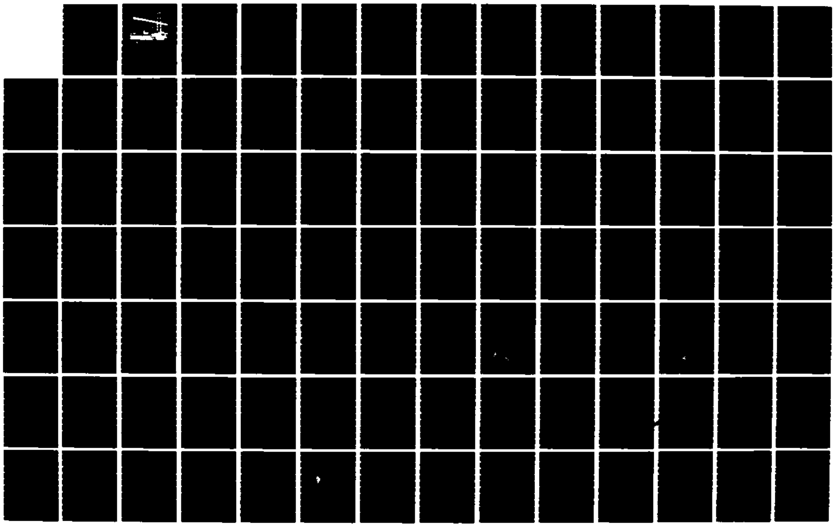
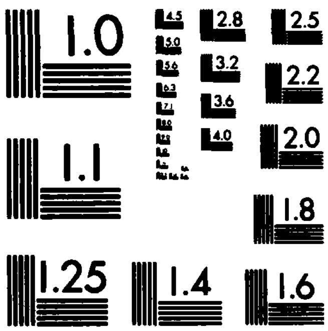
AD-A136 653 ENVIRONMENTAL INVESTIGATIONS AND ANALYSES FOR LOS ANGELES-LONG BEACH HARB..(U) UNIVERSITY OF SOUTHERN CALIFORNIA LOS ANGELES ALLAN HANCOCK F.. DEC 76 1/8

UNCLASSIFIED DACW09-73-C-0112 F/G 8/10 NL




1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6

AD-A136653

ENVIRONMENTAL INVESTIGATIONS and ANALYSES

LOS ANGELES - LONG BEACH HARBORS
1973-1976

FINAL REPORT
to
The United States Army Corps of Engineers
Los Angeles District

by

HARBORS ENVIRONMENTAL PROJECTS
INSTITUTE FOR MARINE AND COASTAL STUDIES
ALLAN HANCOCK FOUNDATION
UNIVERSITY OF SOUTHERN CALIFORNIA
LOS ANGELES, CALIFORNIA 90007

DECEMBER, 1976

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A136 653
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) ENVIRONMENTAL INVESTIGATIONS AND ANALYSES LOS ANGELES-LONG BEACH HARBORS 1973-1976 FINAL REPORT TO THE UNITED STATES ARMY CORPS OF ENGINEERS LOS ANGELES DISTRICT	5. TYPE OF REPORT & PERIOD COVERED
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) HARBORS ENVIRONMENTAL PROJECTS, INSTITUTE FOR MARINE AND COASTAL STUDIES, ALLAN HANCOCK FOUNDATION, UNIVERSITY OF CALIFORNIA, LOS ANGELES, CA 90007	8. CONTRACT OR GRANT NUMBER(s) DACW09-73-C-0112
9. PERFORMING ORGANIZATION NAME AND ADDRESS US ARMY CORPS OF ENGINEERS LOS ANGELES DISTRICT P.O. BOX 2711, LOS ANGELES, CA 90053	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS US ARMY CORPS OF ENGINEERS LOS ANGELES DISTRICT P.O. BOX 2711, LOS ANGELES, CA 90053	12. REPORT DATE DECEMBER 1976
	13. NUMBER OF PAGES 737
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report) UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Copies are obtainable from the National Technical Information Services, Springfield, VA 22151

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

ENVIRONMENTAL INVESTIGATIONS AND ANALYSES FOR

LOS ANGELES-LONG BEACH HARBORS, LOS ANGELES, CALIFORNIA

1973-1976

Final Report
with Addenda

The U.S. Army Corps of Engineers
Los Angeles District

From

Harbors Environmental Projects
Institute for Marine and Coastal Studies
Allan Hancock Foundation
University of Southern California
Los Angeles, California 90007

In partial fulfillment of Contract Number
DACW09-73-0112

This study was carried out through the cooperative efforts of the University, funded by the Corps of Engineers, the Los Angeles and Long Beach Boards of Harbor Commissioners, the Pacific Lighting Service Corporation, and the USC-Sea Grant Program, Department of Commerce (NOAA)

December, 1976

TABLE OF CONTENTS

Cover Photography by John D. Soule:

The research vessel Golden West, with the Vincent Thomas Bridge in the background.

Chapter 1

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

PROJECT BACKGROUND

INTRODUCTION

Alteration of the estuarine marshlands and mudflats at the Los Angeles River basin mouth is not a recent event, but occurred over the past 80-100 years. A map of 1915 shows a number of fills and dredged channels already present at that time (Figure 1.1). Natural mudflats and marshlands may well have furnished habitats for birds, fishes, molluscs, and worms. However, they may also have formed anaerobic sludges that gave off methane gas and/or hydrogen sulfide fumes, leading to complaints from those who worked or lived nearby. Thus, in years past, draining of wetlands was not considered to be a disadvantage in many cases, but a great improvement.

The selection of San Pedro Bay for a harbor was made long before it was conceivable to people that California could run out of natural habitats for estuarine species. It is probably not possible at this point to restore the Los Angeles-Long Beach harbor marshlands to their former state, if only because of the interruption of natural drainage patterns, caused by grading and construction for the surrounding metropolis. Land runoff is channeled and is also contaminated by oil from streets, fertilizers and pesticides from homes and agricultural land, and by industrial wastes.

The primary function of a harbor is to serve the populace by facilitating commerce and industry. It should also be possible, by continuing effort, to maintain water quality that is sufficient to support marine life, to prevent pollution damage to installations, and to make the environment habitable for those who work or live in the harbor area. A bird refuge is probably possible as well, if compatible land use can be mandated for that purpose.

Development of the harbors by deepening channels and filling some areas is necessary to handle the increasing trade for the southern California area and for the western United States as well. A major deepwater port or facility is required for southern California. Of the areas suitable for constructing a harbor, several constitute natural habitats which should be preserved at all costs. Such areas as Morro Bay, Mugu Lagoon and Anaheim Bay can still be kept relatively unpolluted and can perhaps be enhanced as biological preserves.

Alterations to the existing harbors of San Pedro Bay are to be preferred to the alternative of damaging or destroying

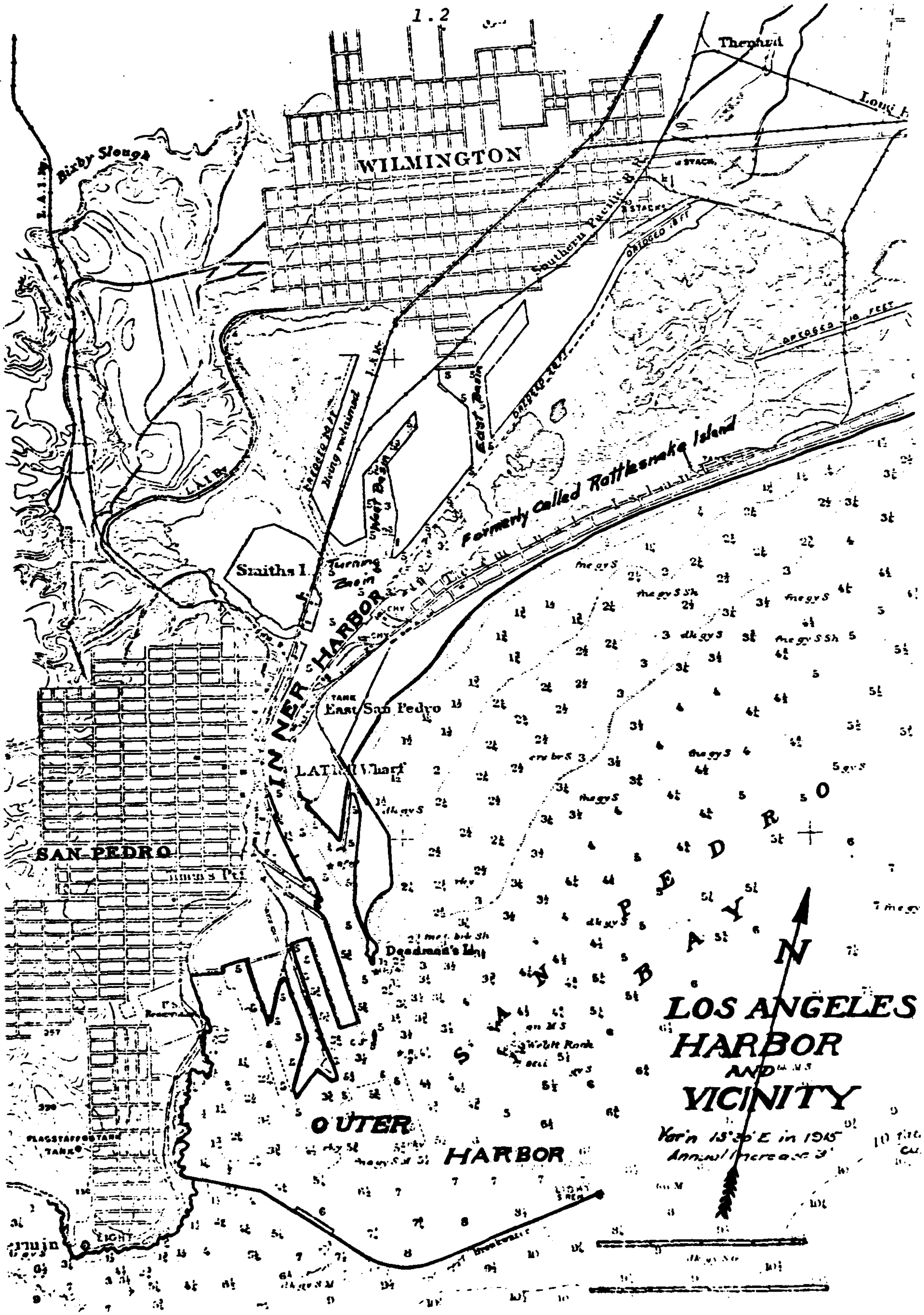

WILMINGTON
Bixby Slough
Southern Pacific
East Basin
Being reclaimed
Formerly Called Rattlesnake Island
Smiths I.
Turning Basin
INNER HARBOR
East San Pedro
SAN PEDRO
Deadman's Id
OUTER HARBOR
SAN PEDRO BAY
LOS ANGELES HARBOR AND VICINITY

Figure 1.1

one of these natural, existing biological habitats.

However, the design of harbor installations must be considered carefully, or the water circulation will be so altered that flushing will be inadequate to maintain minimally acceptable water quality in some areas. If much of the outer harbor water mass is eliminated by filling, populations of marine organisms will be greatly affected, as is discussed in subsequent chapters of this report.

It is clear that some populations such as fish may be greatly decreased due to changes in water mass and habitat resulting from landfill. The harbor is an important nursery ground for young fish. It may not be possible for them to shift to adjacent areas because of differences in food, water circulation, salinity, dissolved oxygen and other factors, including population densities.

Some populations of benthic organisms would be eliminated in areas of dredging and filling, while fouling organisms would find new substrates for habitats when planktonic eggs and larvae settle out of the water column on new pilings and dikes.

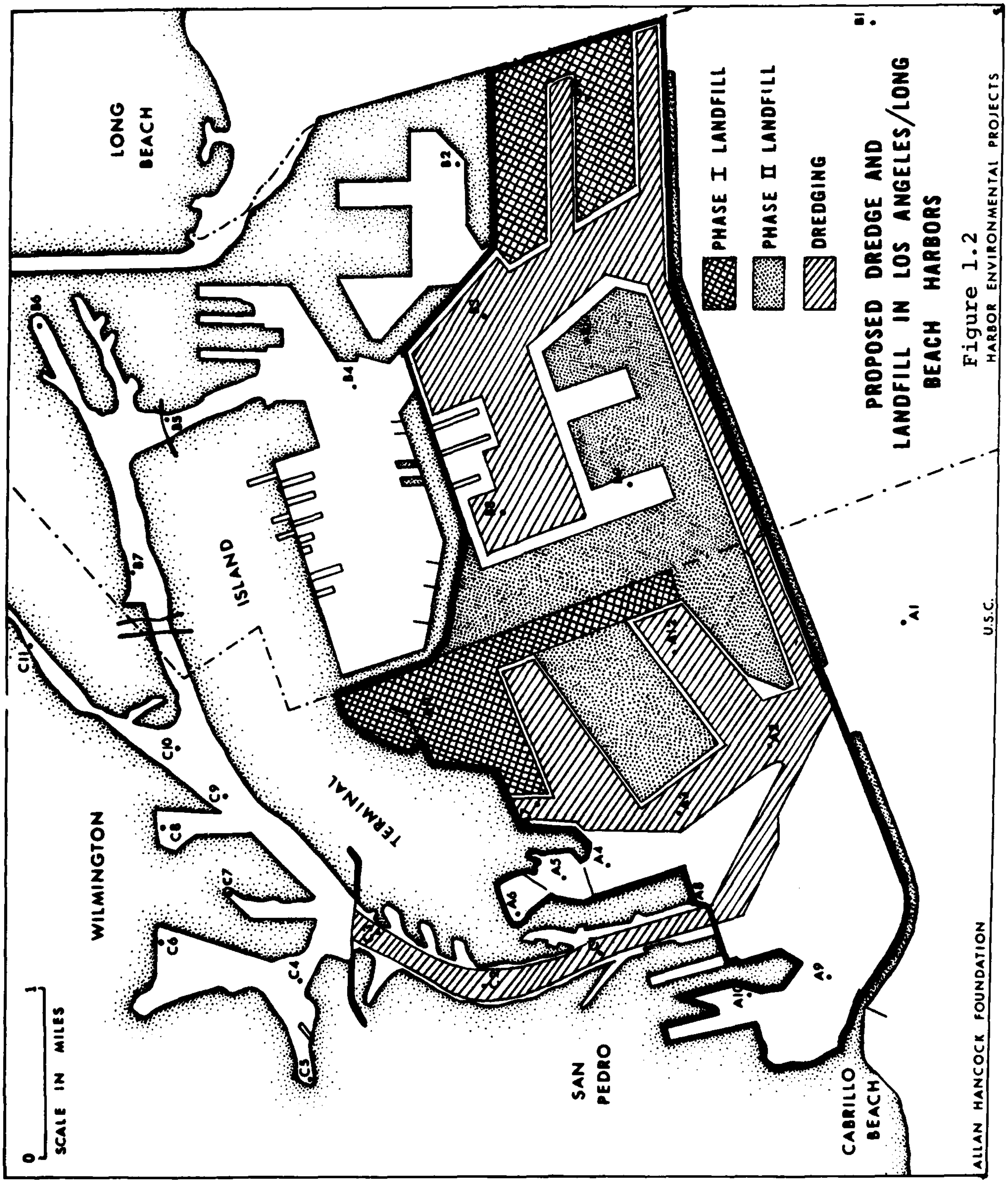
It is therefore very important to know what trade-offs are being made in terms of the environment, in exchange for facilitating the increased trade capacity of the ports. The relative intrinsic and socio-economic values are beyond the scope of this report and are not addressed in it. These factors can only be weighed when extended effort has been made to gather the relevant data and information on which to make decisions.

PROJECT DESCRIPTION

Two projects involving dredging of channels and creation of new landfill within the harbors have been considered and are discussed either in part or in whole in this report.

The Interim Project of the U.S. Army Corps of Engineers is the smallest in scope and involves dredging the Main and Inner Channel and Turning Basin of Los Angeles Harbor to -45 feet and filling the area near Pier 301 and the seaplane base to create about 307 acres of new land. This project was being specifically addressed at the time this study was initiated in 1973.

The Master Plan Project map (Figure 1.2) is a composite of plans forwarded to the Allan Hancock Foundation for consideration of impacts by the Corps of Engineers, Los Angeles District on 18 March 1975, and confirmed on 1 April 1975.



PROPOSED DREDGE AND LANDFILL IN LOS ANGELES/LONG BEACH HARBORS

Figure 1.2

This map is based on drawing 2-2066-1, sent to the Corps of Engineers on 22 January 1975 by L. L. Whiteneck, Chief Engineer for the Los Angeles Harbor, and on drawing HD-8-128-1/5, forwarded to the Corps on 7 March 1975 by B. N. Hoffmaster, Chief Engineer for the Port of Long Beach.

SUMMARY OF PROBABLE IMPACTS

Detailed statements of the probable impacts are contained in the separate sections of this report. At the time of the research for the present study (1973 and 1974) results of physical model studies by the U.S. Army Corps of Engineers Waterways Experiment Station were not available. Those studies that have now been completed have served to emphasize the tentative conclusions expressed below. Revisions have been made in the long-range plan by the Port of Long Beach, and feasibility studies by the Port of Los Angeles are being made. The City of Los Angeles and the California Regional Water Quality Control Board are also studying alternatives for waste disposal at the Terminal Island Treatment Plant. The impacts cannot be quantitatively predicted on the basis of existing knowledge, but good estimates have been made by authoritative experts in the fields covered by the present report.

Short-term Impacts

1. Creation of turbidity and associated perturbations in water quality will occur in the vicinity of dredge and disposal sites. The extent will depend on the location, extent of the area and methods used. Localized loss of benthic, planktonic and fouling organisms will occur due to direct contact, entrainment or siltation. Pelagic biota, such as fish, will be less affected because most will be able to move away from the immediate area of impact. If the zone of dredging is widespread, the impact will deplete the entire harbor area for several months.

2. Oxygen depletion in the immediate area of dredging may be severe due to oxidation reactions of sediments and organics presently existing in reduced oxygen or anaerobic states.

3. Increased levels of microbials may be encountered.

4. Phytoplankton blooms may be engendered.

5. If blasting is required for deepening the water channels, fish kills can be expected in the water column due to shock.

6. The removal of polluted fine surface sediments, by hydraulic dredge, should help to alleviate some of the impact of the immediate oxygen demand (IOD), chemical oxygen demand (COD) and biochemical oxygen demand (BOD) of the sediments. Presently the surface sediments contain high levels of heavy metals, organic load and other pollutants (Chen and Lu, 1974). Tests show that resuspension can cause release of some of these into the water column and possibly into the food chain (Soule and Oguri (eds), 1976).

However, removal of polluted sediments in the area of the Interim Project by dredging, may result in long-term gains of cleaner water. Presently the shallow bottom channels are stirred by winds and ship movements, resulting in recurrent resuspension of polluted sediments. A net improvement would be a long-term gain in exchange for short-term impacts, provided that other factors do not cause a drop in over-all water quality.

7. Construction activities will displace birds seeking nesting, resting and foraging sites. This has already been demonstrated in the past four years relative to Least Tern habitats on Terminal Island. The Terns recolonized the area when earth moving halted in the vicinity, since their habitat had not been eliminated.

Long-term Impacts

1. Permanent loss of habitat due to creation of landfills would result in a reduction of space available for benthic marine organisms. Reductions are generally proportional to the size of the area covered by fill, distinguishing between Interim (Phase I) projects and Phase II (Completions). The immediate loss (short-term impact) of benthic worms in sediments being dredged would presumably be replaced over a period of time by recolonization and succession. Irretrievably lost would be those benthic areas covered by fill. The importance of benthic organisms, particularly polychaete worms, is not generally recognized. In feeding, they filter or consume organic material and bacteria which are thus recycled. The worms themselves furnish a major food source for crustaceans and fishes. The rich bottom fish population is due largely to the extensive benthic worm population.

2. The proposed alterations would also decrease marine faunal biomass. Species composition of the populations would be sharply altered, approximating an extension of faunal assemblages characteristic of the inner harbor into the outer harbor. Changes in the quality of the water mass due to reduced circulation, as well as alterations in the size and

shape of the harbors, would cause decreases in the total biomass. Phase I alterations would cause proportional decreases, but Phase II alterations would be even more extensive, seriously depleting total harbor biota.

3. Changes in fish species and populations of the outer harbor would result from creation of Phase I solid barriers to circulation across the outer harbor. The fill in the seaplane base area would not affect the fish appreciably. The total reduction of harbor water mass by Phase II would result in elimination of the major portion of the fish biomass.

4. The change in remaining faunal assemblages from those characteristic of present outer harbor waters to inner harbor and ship fauna means a strong shift to fouling organisms. New pilings and rip-rap offer extensive substrate for colonization.

5. Areas close to the breakwater may show growth of rocky intertidal zone fauna and flora. Studies along the breakwater, both inside and outside, indicated high algal species diversity (Setzer, 1974) but the animal populations were low (Morris, personal communication). Chapter 13 gives some relevant data for the area. Indications are that the algal community changed greatly between 1973 and 1974, as did the fish population. This is probably due to changes in the thermal regime of the entire southern California coastal waters in those years, and demonstrates the degree to which the harbor can be recolonized following annual shifts in temperature or other abiotic parameters.

6. The potential for recolonization of the harbor after Interim Project construction is presently good, based on information reported in other sections of this report. The rapidity of recolonization depends in part on the rate of flushing in the altered harbor. Recolonization of the biota would probably occur within a few months. Succession would continue for several years before stability is reached. The ultimate determinants of the new climax populations will be the quality and availability of the substrate.

7. Creation of dead-end slips would probably result in a reduction in water circulation, posing potential problems in water quality. Reduced oxygen levels and creation of conditions conducive to massive phytoplankton blooms such as Red Tides may be expected. Water circulation and flushing would be severely altered if the solid land barriers proposed for Phase I are created, along the center of the outer harbor by the Port of Los Angeles and between Pier J and Queens Gate by the Port of Long Beach. Corps of Engineers Waterways Experiment Station (WES) model studies have caused the Port of Long Beach to modify their design extensively for the Pier J extension, to use trestles and a

breakwater in place of solid fill. This would ameliorate much of the reduction in flushing of the harbor area east of Pier J. However, much of the dredge spoil must be disposed of elsewhere in order to accomplish this.

8. Reduction in bird nesting habitat is probable for the endangered Least Tern unless specific planning for new habitats takes place prior to initiation of construction. Birds such as Pelicans fish the area of the Interim Project extensively, and rest on the quiet breakwaters of the seaplane base. Bird biomass probably would not be permanently altered by Phase I projects, but diversity of species would probably decrease. The less numerous species would most likely be replaced by larger dock populations of gulls.

Phase II projections would seriously reduce diversity and perhaps biomass due to extensive loss of fish populations on which the marine-associated birds feed.

9. Consensus has not been reached as to the socio-economic need for Phase II landfills, and trade-offs cannot be evaluated in terms of biological and water quality parameters. However, trading losses of a major nursery ground for fish and a rich habitat for the food web invertebrates for harbor facilities must be considered with caution. The total reduction in wetlands in California suggests that population loss in the harbors will not be compensated for by increased populations in other nearby areas. These may already be at carrying capacity, or may not offer suitable substrates or food.

RECOMMENDATIONS

1. Major dredging operations should be confined primarily to late fall and winter periods, when minimal settling organism activity occurs.

2. Dredging should not be undertaken in several large areas simultaneously, so that fish can avoid the area and reproductive species will be sustained in peripheral areas for repopulating the area following dredging.

3. Best practicable dredging technology should be employed to minimize turbidity and widespread oxygen depletion.

4. Polluted fine silts carrying adsorbed heavy metals, pesticides, and organics should be contained and possibly treated to prevent reentry of pollutants into the water column. This would be of permanent benefit to the harbor. Ocean disposal may not be appropriate if fines will not sink and become distributed through the water column.

5. Harbor design and construction should be concerned with obtaining maximum flushing within the harbor, and between the harbor and outside waters, in order to maximize water quality.

6. Massive fills of Phase II will permanently destroy much of the biological quality of the harbor. Alternatives to massive fills should be given serious consideration. Solid barriers to circulation should be avoided, especially where alternatives such as trestles can be designed. An island landfill connected with Terminal Island by a roadway that does not block circulation should be studied in the WES model as an alternative. The size of the total landfills planned for Phase II should be greatly reduced.

7. Provision for Least Tern habitats should be made during planning. Other species require adequate feeding and resting areas.

HISTORY OF THE HARBORS

San Pedro Bay, in southern California, consists of the shallow waters east of Palos Verdes Peninsula, extending southeastward to Newport Bay. The shallows are largely the result of depositional sediments from the Los Angeles and San Gabriel River basins, extending seaward to about the 150 foot depth contour.

The Los Angeles-Long Beach Harbors were developed from the estuarine outlets of the Los Angeles and San Gabriel Rivers and from the shallow depths of San Pedro Bay. The geologic history of the area is by no means static. The Los Angeles River at times flooded much of the present southern portion of the Los Angeles basin, forming a lake, and at times flowed west on the north side of the Palos Verdes Peninsula, emptying into Santa Monica Bay. In recent times the natural course of the river flowed through the Cerritos Channel area, spread over mud flats and salt marshes, and exited primarily at the present main channel area.

The paleontological record (Kennedy, 1975) indicates the periods in which the entire area was submerged in seas, to be followed by receding waters and changing shoreline conditions. Thus the basin contains extensive sedimentary deposits, reworked by subsequent basin drainage patterns, and much unstable fine sediment in the harbor (Figure 1.3, Table 1.1, Figure 1.4).

The arid, Mediterranean-type climate modifies the estuarine nature of the area, because the annual rainfall, which averages about 13 inches, falls mostly between November and April. The basin lacks the year-round freshwater input and salinity gradients that characterize a true estuary (Abbott et al., 1973). The terrestrial vegetation has been termed a "fire ecology" because dry grasses burn off in the summer and many plants are fire resistant. Seeds of the California oak, for example, often germinate only after heating by grass fires. The basin was called Bahia de Los Fumos (Bay of Smokes) by the Spanish explorer Cabrillo, who observed the clouds of smoke from grass fires when he visited the bay.

The estuary, in the early days of Spanish California, had shallow channels which flowed in a crescent, from the present Cerritos Channel area behind Rattlesnake Island, curving around through the present East Basin Channel to the main channel in San Pedro. The entrance to the present main Los Angeles Channel was shallow, with a sand bar and Deadmans Island at the entrance, so that only about a 2-foot clearance was present at low tide.

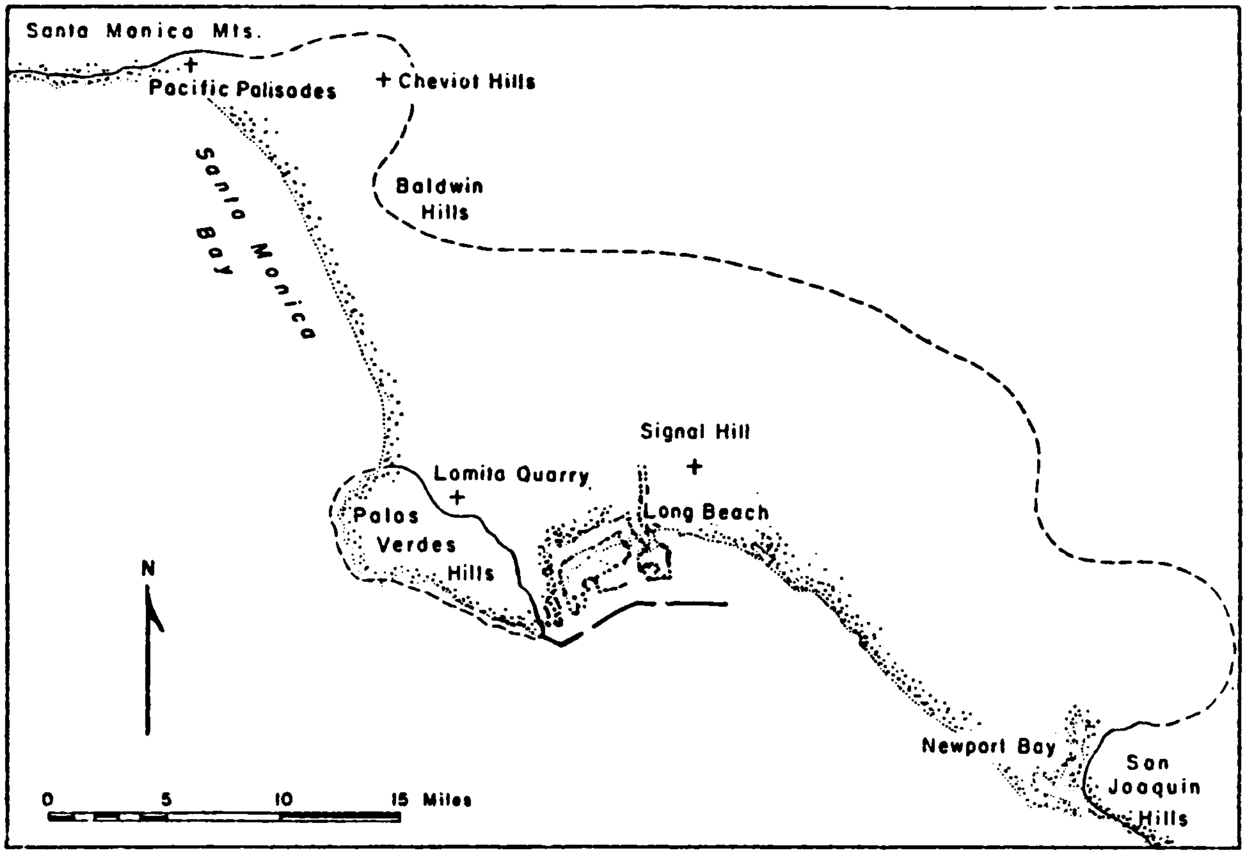


Figure 1.3

Sketch map of the Los Angeles basin showing the inferred position of the shore line during high sea stand on terrace 1 at Palos Verdes Hills, on the Dume terrace in the north, and on an unnamed low terrace in the San Joaquin Hills to the south; this is dashed where covered. Dotted line is present coast line. Lower Pleistocene localities have no relation to coast lines shown. (After Valentine, 1961, p. 366, fig. 6; from Kennedy, 1975).

Table 1.1

Paleoecology

INFERRED MARINE ENVIRONMENT
(abstracted from various sources)

AGE	FORMATION	DEPTH	TEMPERATURE (°C)	OTHER
Pleistocene	Palos Verdes Sand	0-27m	11°-21° (mollusks) 13°-18° (ostracods)	Contains Surian (Warm water) mollusks
Pleistocene	San Pedro Sand	18-27m at top 92m at base	11°-14° (mollusks) (7° at 92m)	
Pleistocene	Timms Point Silt	137-183m at top 46-92m at base	11°-14° (mollusks) (5°-8° at 92m) 13°-18° (ostracods)	
Pleistocene	Lomita Marl	46-92m at top 92-183m at base	11°-21° (mollusks) 13°-13° (ostracods)	Contains both northern and southern species
Pliocene	Fernando Formation	0(?)-46m	similar(?) to southern California now	Mollusks chiefly sandy bottom
Pliocene	"Repetto" Formation	2000-2500m		
Miocene	Malaga Mudstone	>915m	similar(?) to southern California now	
Miocene	Valmonte Diatomite	"bathyal"	similar(?) to southern California now	
Miocene	Altamira Shale	180-915m		Contains tropical mollusks

Source: Kennedy, 1975.

Richard Henry Dana (1869) reported that, before 1850, ships anchored off Pt. Fermin and goods were lightered ashore. Bundles of hides from the ranches were pushed over the cliffs and retrieved below, in the area between Pt. Fermin and Timms Point (near 15th Street). Most of this area became Fort MacArthur. In 1858, a wharf and warehouse were built by Phineas Banning at the head of the harbor, in the present Wilmington area, replacing the cliffside operations (Beecher, 1959).

The first railroad in southern California, the Los Angeles and San Pedro, was completed in 1869, and linked on the north with the Southern Pacific and Central Pacific Railroads. To the east, the Southern Pacific linked with the Texas Pacific in 1883, and finally with the Atlantic and Pacific and the Atcheson, Topeka and Santa Fe. Later the Los Angeles-San Pedro was absorbed by the Salt Lake Railroad, which owned about 1500 acres of land in the harbor in 1905. This holding later figured in litigation over the ownership of tidelands in the harbor.

San Pedro was not made a customs port of entry when California came into the Union, but was made a port of delivery in 1853; the lack of customs probably hindered the growth of commerce at the port. In 1871, the federal government began a 6,700 foot jetty to connect Rattlesnake Island (now part of Terminal Island) with Deadmans Island (destroyed by dredging of the main channel and filling the tip of Reservation Point). Commerce jumped from 50,000 tons in 1871, to 450,000 tons in 1888 (it was more than 52 million tons in 1972 and 1973). The jetty was first built of timber because of the scarcity of stone, but rapidly disintegrated under the attacks by boring organisms such as *Teredo*, and had to be rebuilt with stone within a short period.

Competition for a "deepwater" port was fierce between Santa Monica and San Pedro. C. P. Huntington and the Southern Pacific Railroad wanted an exclusively held port in Santa Monica Bay. Other rail magnates, Congressmen such as Sen. Leland Stanford, and the Army Engineers fought for a "free port" in San Pedro.

The engineering officer of the port recommended a 7,000 foot breakwater off Pt. Fermin in 1866. Again in 1890, a breakwater was proposed for San Pedro. A Board of Engineers recommended to Congress in 1892 that San Pedro Bay be selected because it afforded better protection from prevailing winds and dangerous storms than did Santa Monica Bay, and because interior harbor protection was already available at San Pedro. Finally, construction was begun in 1899, and the 11,050 foot San Pedro breakwater was completed from the present Cabrillo Beach to the west side of the present

Angels Gate in 1910, sheltering 350 acres. The Main Channel opening for the Port of Long Beach was dredged in 1909.

In 1923, the Los Angeles River Channel was diverted from its course in Cerritos Channel to flow into the bay at Long Beach. Channelizing and dams upstream have controlled the extensive flooding formerly experienced by the basin, but this has reduced the offshore formation of sand to replenish beaches, and almost eliminated freshwater input to the harbor. At present, storm drains and the Terminal Island sewage treatment plant furnish the only significant freshwater components.

The present harbor is bounded by three sections: The San Pedro breakwater, the middle breakwater and Long Beach breakwater. The latter two sections were completed in 1928. Extensive changes in the harbor have included the construction of the Navy mole in the 1930's and Piers A-J in Long Beach, which were completed in 1971. (See Figure 1.5)

The harbor waters are divided politically into three areas. On the west is the Port of Los Angeles, of the City of Los Angeles, which extends eastward to the middle of Terminal Island and the Navy mole (Figure 1.6). The easterly sections are mostly in the City of Long Beach; the Port of Long Beach occupies the middle portion. To the east are harbor waters not included in the port. In terms of general usage, San Pedro Harbor refers to the entire water area behind the breakwaters. Los Angeles Harbor usually refers to the Port of Los Angeles, but has been used to identify the entire harbor. Long Beach Harbor may mean only the Port of Long Beach or may include the waters east of Pier J.

LITERATURE CITED

Abbott, B.C., D.F. Soule, M. Oguri and J.D. Soule. 1973. In situ studies of the interface of natural and man-made systems in a metropolitan harbor. Helgolander Wiss. Meers. 24(1-4): 455-464.

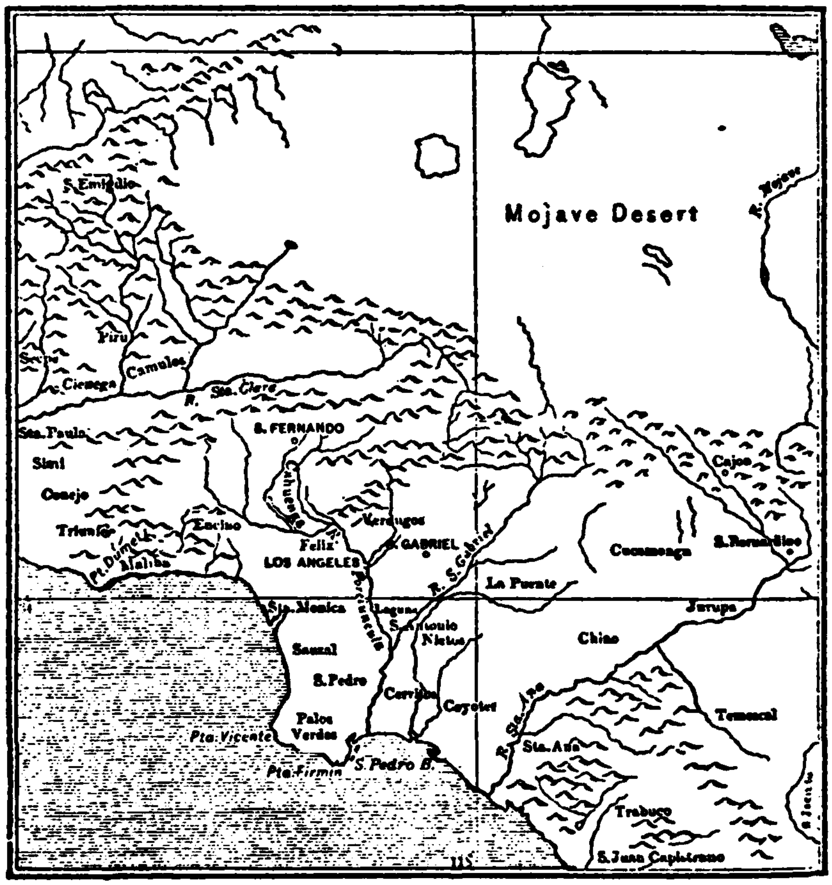
Bancroft, H.H. 1884. History of the Pacific States of North America. Vol. 13, California. Vol. I, 1542-1800. A.L. Bancroft & Co., San Francisco. 744 p.

Beecher, J. 1915. History of Los Angeles Harbor. University of Southern California Thesis.

Kennedy, G.L. 1975. Paleontological record of areas adjacent to the Los Angeles and Long Beach Harbors, Los Angeles County, California. In Marine Studies of San Pedro Bay, California. Part 9 Paleontology. Allan Hancock Foundation and U.S.C. Sea Grant Program, University of Southern California. USC-SG-4-75: 1-119.

1.15

Setzer, R. 1974. Preliminary investigations of benthic marine algae from the breakwaters protecting Los Angeles and Long Beach Harb o rs. In Marine Studies of San Pedro Bay, California. Part 4. Environmental Field Investigations. Allan Hancock Foundation and U.S.C. Sea Grant Program. University of Southern California USC-SG-74: 89-101.



MAP OF LOS ANGELES REGION IN 1800.

Figure 1.4

Source: Bancroft, 1884.

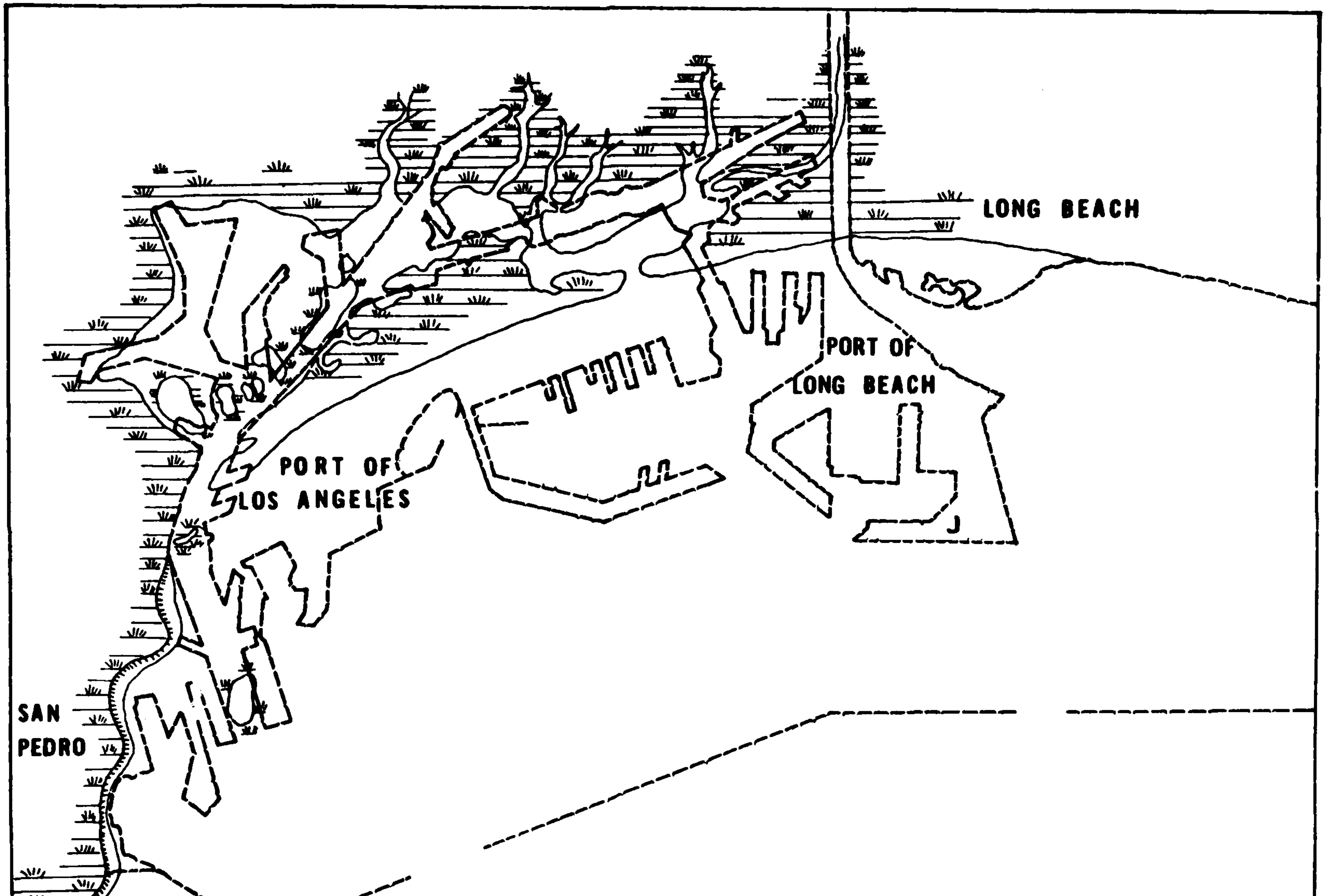


Figure 1.5. Comparison of 1871 Survey of San Pedro Bay with Present Configuration Superimposed (dotted lines).

Source: Port of Long Beach.

SCOPE OF THE STUDY

The Los Angeles-Long Beach Harbors had never had extensive biological, physical or chemical surveys until the initiation of the present studies by Harbor Environmental Projects of the University of Southern California, in spite of the fact that they form one of the major ports in the United States and house a Navy base. Under the impetus of the National Environmental Policy Act and subsequent legislation, private industry and public agencies found a need for environmental information that did not exist or was unavailable to them. Accordingly, a baseline survey and monitoring program was begun by the University for the outer Los Angeles Harbor in 1971, under sponsorship of Pacific Lighting Service Corporation. This was expanded in 1972 under the U.S.C. Sea Grant Program (Department of Commerce - NOAA) and contracts with the Los Angeles Board of Harbor Commissioners. The U.S. Army Corps of Engineers, Los Angeles District, in 1973 contracted to extend the program to cover the entire harbor, and added parameters to be studied.

In order to determine the probable impact of port development, the expanded cooperative effort has permitted the gathering of abiotic data on temperature, salinity, oxygen, pH, and turbidity through the water column, on nutrients such as ammonia, nitrite, nitrate and phosphate, on sediment character and the incidence of trace and heavy metals, and circulation patterns. Biotic measurements included phytoplankton, benthic organisms, microbiology, water associated birds, and ichthyology, as well as evaluating the biotic quality of the water column with settling racks.

Following field collection, weight or volume density were made and determinations, identifications of organisms to species level were carried out. All data were entered in IBM 370 Computer, and analytical techniques were performed to determine the significant relationships between the biotic and abiotic parameters.

A total of 43 stations was selected to be monitored for this study (see Figure 1.6). The locations were carefully chosen to permit the optimal coverage of areas and to seek patterns of variability within the scope of our facilities. These stations were divided into regional groups for convenience in dealing with the operational time and work load constraints involved in the program of sampling and data analysis. Group A, consisting of 12 stations, covers outer Los Angeles Harbor, including Fish Harbor and the Los Angeles Harbor sea buoy. These stations were occupied during the first week of each month. The B group of stations

was routinely sampled during the second week of each month. These stations were located in the Port of Long Beach at the Long Beach sea buoy. Stations in Inner Los Angeles Harbor were designated the C stations and were occupied during the third week of each month. The D stations, in the area to the east of Pier J, Long Beach, were sampled during the fourth week of each month. The usual day of the week when the sampling was carried out was Wednesday.

Monthly sampling at each station included instrumental measurement of water temperature, salinity, pH, dissolved oxygen and turbidity at one meter intervals through the water column. Surface water samples were collected for analysis of dissolved oxygen by Winkler titration, BOD, NO_3-N, NO_2-N, NH_3-N, PO_4-P and sulfide. Biological sampling included collection of surface water for determination of bacterial populations including coliforms, phytoplankton productivity and chlorophyll *a*. A surface tow was also made for zooplankton, using a 253 micron mesh ½ meter net equipped with a flow meter. Settling racks were deployed monthly at 24 stations throughout the harbor to sample water column fauna. Separate sampling operations were conducted for fish collections and for bird census.

At approximately quarterly intervals each station was sampled for determination of sediment grain size and benthic fauna, using either a modified Reinecke box corer or a small Campbell grab. Data records and samples were returned to the laboratory for further processing and analysis. Special samples were also taken for analysis of trace and heavy metals and chlorinated pesticides.

In the summers of 1973 and 1974, one series of dives were made to sample the breakwater biota at the H stations. Stations H1-6 were on the inside of the breakwater, and H7-12 were opposite these on the outside. H1 and H7 are on the San Pedro Breakwater, H2,3,4,8,9, and 10 are on the middle breakwater, while H5, H11 and 12 are on the Long Beach Breakwater.

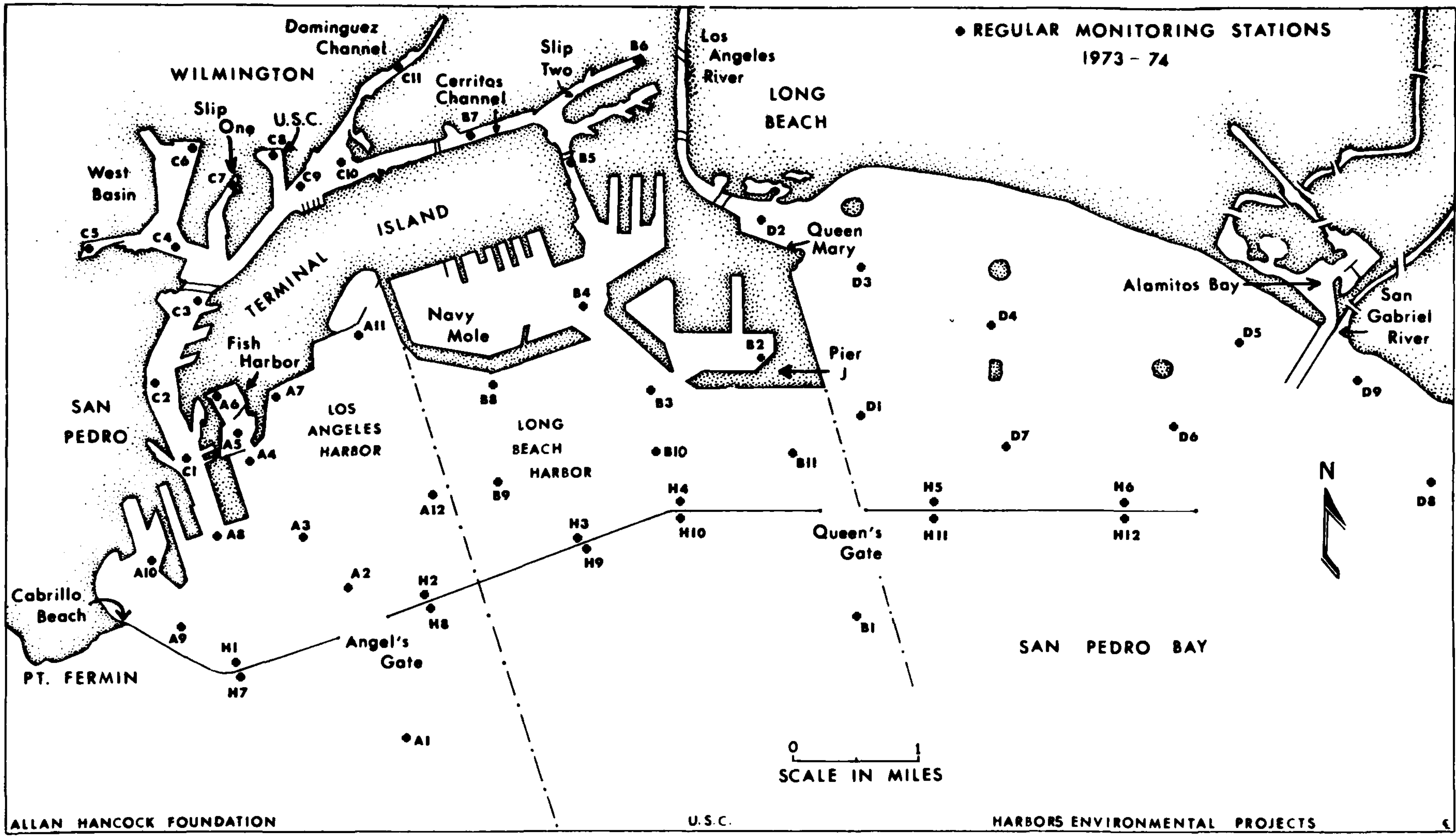

• REGULAR MONITORING STATIONS
1973 - 74
WILMINGTON
Dominguez Channel
Slip One
U.S.C.
West Basin
Cerritos Channel
Slip Two
Los Angeles River
LONG BEACH
TERMINAL ISLAND
Fish Harbor
Navy Mole
Queen Mary
Pier J
Alamitos Bay
San Gabriel River
SAN PEDRO
LOS ANGELES HARBOR
LONG BEACH HARBOR
Cabrillo Beach
PT. FERMIN
Angel's Gate
Queen's Gate
SAN PEDRO BAY
N
0
1
SCALE IN MILES
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
A1
A2
A3
A4
A5
A6
A7
A8
A9
A10
A11
A12
B1
B2
B3
B4
B5
B6
B7
B8
B9
B10
B11
D1
D2
D3
D4
D5
D6
D7
D8
D9
H1
H2
H3
H4
H5
H6
H7
H8
H9
H10
H11
H12
ALLAN HANCOCK FOUNDATION
U.S.C.
HARBORS ENVIRONMENTAL PROJECTS

Figure 1.6

DESCRIPTION OF HARBOR STATIONS

Outer Los Angeles Harbor (Port of Los Angeles)

A-1.

1. At the Sea Buoy located 3/4 nautical mile due south of Angels Gate, Los Angeles breakwater.
2. Depth 66 feet.
3. Winds are unrestricted.
4. Surroundings: Shipping going directly by the location. Possibly subjected to discharges from ships, terminal discharges from the cooling systems for the engines and bilge or sewer discharges before they enter the harbor.
5. Comments: The area is generally well swept by the prevailing currents outside the harbor.
6. Latitude: 33° 41' 57"; Longitude: 118° 14' 33"

A-2.

1. At Coast Guard Buoy R4, located 3/4 nautical mile NW of Angels Gate.
2. Depth approximately 30 feet.
3. Winds from the SW, are unobstructed.
4. Surroundings: Subjected to vessels, both industrial (large tankers, etc.) and pleasure boats. Gurry from the cannery outfall has been seen in this area, and according to USC drogue study the wind drives the surface waters from around A-9 over to the A-2 area.
5. Latitude: 33° 43' 55"; Longitude: 118° 15' 14"

A-2a. (Special benthic station)

1. Located inside the harbor approximately ½ nautical mile.
2. Depth about 40 feet.
3. Winds from the SW unobstructed.
4. Surroundings: Increase in ship traffic, in both commercial and pleasure boats. Cannery wastes in the form of coagulated or flocculent material (gurry) occur occasionally.
5. Latitude: 33° 43' 00"; Longitude: 118° 15' 14"

A-3.

1. At Coast Guard Buoy R2, located due east of Reservation Point.
2. Depth approximately 21 feet.
3. Winds are sometimes obstructed by Reservation Point, the houses, trees, etc., forming a lee.
4. Surroundings: Directly in line with the channel into Fish Harbor, used by many fishing boats. Gurry seen more frequently here, and the waters are subjected to boat discharges, more from the tuna fishing boats than from the large tankers and pleasure craft.
5. Latitude: 33° 43' 28"; Longitude: 118° 15' 37"

A-4.

1. Located outside the mouth of Fish Harbor.
2. Depth: The channel is dredged to 22 feet and the bottom on either side of this channel is approximately 13-14 feet in depth.
3. Wind varies, due to extensive obstruction caused by the buildings and trees on Reservation Point.
4. Surroundings: This area is outside the breakwater of Fish Harbor and east of Reservation Point where the Coast Guard and a prison are located. The breakwater of Outer Fish Harbor is a favorite place for fishermen. Cannery effluent is carried into this area; white, red, and green tides have been observed here.
5. Latitude: 33° 43' 49"; Longitude: 118° 15' 50"

A-5.

1. Located in Outer Fish Harbor.
2. Depth: The channel is 22 feet deep, but the bank of this channel on the west side is approximately 13 feet in depth and on the east it is 22-23 feet, so it has been dredged out in the past.
3. Winds variable, due to surrounding buildings; generally not as intense as in the Outer Harbor.
4. Surroundings: The east side area is used by the Los Angeles Yacht Club, and there is a marina on the west side as well as a boat yard. There is a cooling water discharge from StarKist Foods. The area might be subjected to raw sewage from the vessels that are moored in the marinas. Fishing boats offload in this area and have been observed observed dumping cleaning water directly into the area. The boat yards on the west side use ordinary paint and anti-fouling paint. Dust and chips from these paints are sometimes blown out into the water.
5. Latitude: 33° 43' 57"; Longitude: 118° 15' 56"

A-6.

1. Located in the NW sector of Inner Fish Harbor.
2. Dredged to approximately 18 feet.
3. Prevailing winds vary due to obstruction, except during Santa Ana conditions when the winds come from the north or northeast without much obstruction.
4. Surroundings: There is limited circulation of the waters in this area. Industries include boat yards and canneries. Boat traffic is frequent and fishing vessels are here. A Fire Department pier in the NW corner is used for settling racks.
5. Latitude: 33° 44' 09"; Longitude: 118° 16' 00"

A-7.

1. Located due east of Fish Harbor and Pier 302.
2. Depth shoals from 17 feet.
3. Winds from the SW eddy to the north around the breakwater. The surface currents mainly follow the wind direction, and there are usually extensive amounts of fish gurry here.

A-7, cont.

4. Surroundings: There are two discharges from the canneries to the west, from Pier 301, and one main sewer outfall from the Terminal Island primary treatment plant to the east. There is little boat traffic, but people use the breakwater and cannery discharge area for fishing spots. A salvage operator is presently dismantling hulks in the water area.
5. Latitude: 33° 44' 12"; Longitude: 118° 15' 26"

A-8.

1. Ships beacon, dolphin, located about 200 yards south of Reservation Point at the entrance to the main Los Angeles Channel.
2. Depth: Approximately 20 feet deep, shoaling toward Reservation Point on the north, and deepening to approximately 35 feet in the main channel to the west and south.
3. Winds from the SW variable.
4. Surroundings: Extensive commercial and pleasure boat traffic. There is a bulk loading area due west across the channel, where coal and iron ore are handled. Some of this material may be blown into these waters when SW winds are strong.
5. Latitude: 33° 43' 13"; Longitude: 118° 15' 58"

A-9.

1. Located due east of Cabrillo Public Beach about ¼ nautical mile and due south of Union Oil dock.
2. Depth 47 feet. This is a dredged channel. It shoals to 24 feet immediately west of this station.
3. Winds from the SW are affected by Pt. Fermin and the breakwater.
4. Surroundings: Some industrial and Navy boat traffic; also extensive pleasure craft traffic due to the water skiing area and boat launch facilities for pleasure craft adjacent to Cabrillo Beach.
5. Latitude: 33° 42' 43"; Longitude: 118° 15' 58"

A-10.

1. Located in the West Channel of Watchorn Basin.
2. Depth: dredged to 36 feet.
3. Surroundings: North of this location is the U.S. Navy refueling wharf. To the north and east are extensive public marinas. Raw sewage might be dumped into the waters by Navy ships and by the private boats moored in this area, as some people live on their boats. Boat traffic is mainly pleasure craft, especially in summer. San Pedro Boat Works is on the peninsula southeast of A-10.
4. Latitude: 33° 43' 02"; Longitude: 118° 16' 38"

A-11.

1. Located due south of the seaplane anchorage and due west of the Navy mole on Terminal Island.
2. Depth approximately 14 feet.
3. Winds from the SW unrestricted.
4. Surroundings: There is no industry on shore in this area, except for limited Navy activity. Boat traffic consists of limited pleasure or Navy craft. Due to the prevailing wind conditions, the surface waters from the outfalls near A-7 often move into the A-11 area, as shown in dye studies in 1971-72.
5. Latitude: 33° 45' 49"; Longitude: 118° 14' 46"

A-12.

1. Located about 1 nautical mile due south of the Navy mole.
2. Depth approximately 33 feet.
3. Prevailing winds from the SW are not obstructed.
4. Surroundings: This is an open area, used as an anchorage by large vessels (tankers, cargo vessels, bulk loaders, etc.) It is also used by commercial bait fishermen, and by pleasure craft. Vessels probably discharge waste here -- bilge or wash water from hulls, holding tanks, etc. -- in violation of regulations.
5. Latitude: 33° 43' 35"; Longitude: 118° 14' 08"

Port of Long Beach

B-1.

1. Location: 3/4 nautical mile south of Queens Gate.
2. Depth approximately 63 feet.
3. Winds unrestricted.
4. Surroundings: Shipping goes directly by this location, which may be subjected to discharges from the ships. The area is generally well swept by the local currents and winds. The environment is very much like A-1.
5. Latitude: 33° 42' 41"; Longitude: 118° 10' 58"

B-2.

1. Location: at inner end of Southeast Basin, adjacent to Berth 243 on Pier J in Long Beach.
2. Depth approximately 45-46 feet.
3. Winds: Variable and less intense than outside the Pier J area, due to the obstructions on the pier.
4. Surroundings: General freighter traffic, cargo containers, offloading at the various piers. Also a molasses terminal for offloading vessels.
5. Comment: Circulation pattern, as shown by the drogue study, is very restricted; surge occurs in the basin entry.
6. Latitude: 33° 44' 31"; Longitude: 118° 11' 37"

B-3.
1. Located due west of Southeast Basin entrance approximately ½ nautical mile.
2. Depth: Channel dredged to 60 feet. Water depth on either side of this channel is approximately 57 feet.
3. Winds moderated by Pier J.
4. Surroundings: Subjected to heavy traffic by large vessels and pleasure craft. Due to the location of Pier F to the NE, this area is subjected to reflected wave action in the late afternoon, and unusually high wind chop builds up approximately 1½ to 3 feet in height.
5. Latitude: 33° 44' 22"; Longitude: 118° 12' 37"

B-4.
1. Located between East and West Basin entrances, on the main channel.
2. Depth approximately 60 feet.
3. Surroundings: Large vessels and pleasure boats utiliza this area. It is also the entrance to the Naval Facility piers. The Navy has not permitted entry into their facility area for this study. The basin may be a source of pollutants from ships and ship services.
5. Latitude: 33° 45' 03"; Longitude: 118° 13' 03"

B-5.
1. Located adjacent to the fire boat dock beneath the Gerald Desmond Bridge.
2. Depth 47 feet. A dredged channel.
3. Variable winds, not as intense as in the outer harbor except during Santa Ana conditions, when winds are from the north or northeast.
4. Surroundings: Numerous red tides have been seen in this area during the summer and early fall. Boats move along berths 35 and 36, southeast of this location. On the west side of the channel, are the Edison power plant and discharges (not now on line), and oil fields.
5. Latitude: 33° 45' 51"; Longitude: 118° 13' 11"

B-6.
1. Location at easternmost end of Channel Two.
2. Depth about 41 feet. The chart indicates shoaling in that area.
3. Wind is minimal, gusty under strong conditions because of the buildings.
4. Surroundings: Various small shipyards in this area. To the north is an oil terminal offloading dock, and oil spills have been seen here. Water circulation is extremely restricted. Red tides have also been seen.
5. Comment: Approximately ½ nautical mile SW of this location is Proctor & Gamble's processing plant and just SW of that plant is a marina which may contribute raw sewage to this general area.
6. Latitude: 33° 46' 35"; Longitude: 118° 12' 34"

B-7.

1. Located in Cerritos Channel approximately ¼ nautical mile NE of the Henry Ford Bridge.
2. Depth approximately 60 feet in the channel shoaling to about 19 feet along the banks.
3. Winds variable. It is not greatly affected by Santa Ana conditions or the prevailing SW winds.
4. Surroundings: Just west of this area marinas are located on both sides of the channel, and north and south of this location are the Union Pacific Railroad oil fields. Settling tanks on the south side of the channel have been seen discharging into the channel. There is a terminal discharge north of this area, and there may be fresh water run-off from storm drains.
5. Latitude: 33° 46' 05"; Longitude: 118° 14' 04"

B-8.

1. Located at the Navy degaussing range in the outer harbor. This area is approximately ¼ nautical mile south of the Navy mole in outer Long Beach Harbor.
2. Depth about 33-40 feet.
3. Winds from the SW unrestricted.
4. Surroundings: Pleasure boats frequent this area but limited ship traffic occurs because it is restricted for the degaussing range.
5. Latitude: 33° 44' 05"; Longitude: 118° 13' 43"

B-9.

1. Located about 1 nautical mile due south of the Navy mole, 3/4 mile south of the degaussing range.
2. Depth approximately 40 feet.
3. Winds from the SW unrestricted.
4. Surroudings: This is in the restricted anchorage area #1 for vessels, and pleasure boats pass this way frequently. The area is also used for fishing for commercial bait fish.
5. Latitude: 33° 43' 35"; Longitude: 118° 13' 28"

B-10.

1. Located 1 nautical mile south of the entrance to Long Beach Main Channel in the restricted anchorage area #1.
2. Depth approximately 60 feet.
3. Winds from the SW unrestricted.
4. Surroundings: The area is used for anchorage, for pleasure vessels and bait fishing.
5. Latitude: 33° 43' 48"; Longitude: 118° 12' 39"

B-11. (optional station)

1. Located approximately ½ nautical mile NW of Queens Gate.
2. Depth approximately 65 feet in the center of the Long Beach Main Channel.
3. Winds from the SW unrestricted.
4. Heavy ship traffic in the area going to and from the offloading facilities in Long Beach Harbor.
5. Latitude: 33° 43' 50"; Longitude: 118° 11' 54"

Main Channel and Inner Los Angeles Harbor (Port of Los Angeles)

C-1.

1. Located adjacent to Berth 73A, approximately ½ nautical mile north of the entrance to the Los Angeles Main Channel.
2. Depth 28 feet on the W. side, 35 in the center of the channel.
3. Variable winds, due to the buildings along the Main Channel.
4. Surroundings: Fishing vessels are moored in the adjacent small basin, and there is a fish terminal immediately to the SW. Across the channel to the west is Bethlehem Steel Shipyard. There is a tank farm and offloading area operated by GATX Terminals, approximately ¼ mile to the south. Heavy boat traffic including freighters of various sizes, fishing vessels and pleasure craft.
5. Latitude: 33° 43' 43"; Longitude: 118° 16' 18"

C-2.

1. Located approximately 1 nautical mile north of the entrance of the Main Channel, adjacent to Berth 84.
2. Depth approximately 35 feet.
3. Winds variable, generally from the south.
4. Surroundings: Industry is restricted to Wilmington Transportation Company, which operates the H-10 water taxi. Heavy boat traffic, mainly freighters, tankers and pleasure craft. The Los Angeles Harbor patrol boat docks are here.
5. Comment: This is a cable and pipeline crossing area, and sewage pipe breaks were reported there in June 1973 and February 1974. Leakage appears to have continued.
6. Latitude: 33° 44' 19"; Longitude: 118° 16' 34"

C-3.

1. Located about 1½ nautical miles north of the main entrance to the channel, below the Vincent Thomas Bridge. Across from the Catalina seaplane terminal, at the Fire Department docks. This is the entrance to the turning basin, and near the LASH terminal.
2. Depth approximately 35 feet.
3. Wind generally from the SW. Not as intense as the Outer Harbor.
4. Surroundings: Industry is mainly freighter traffic, cargo offloading transportation facilities, and the Catalina seaplane terminal. There is a fuel depot due north of this location, about ¼ nautical mile away on the north side of the turning basin.
5. Comment: There is intense ship traffic in this area; freighters, tankers and pleasure vessels.
6. Latitude: 33° 44' 55"; Longitude: 118° 16' 12"

C-4.
1. Located at the junction of Southwest Slip and West Basin, due north of Berth 102.
2. Depth approximately 36 feet.
3. Winds variable, but the area may be subjected to Santa Ana conditions.
4. Surroundings: Industry is heavy ship building at Todd Shipyards due south of this location. There is a banana offloading terminal to the north, and a Union Oil terminal to the east, at Berth 148. Fuel barges are moored to the NW at Berth 122. This area is frequented by freighters, tankers and pleasure craft in moderate numbers.
5. Latitude: 33° 45' 23"; Longitude: 118° 16' 27"

C-5.
1. Located at east end of Southwest Slip, due south of Berth 115.
2. Depth 26 feet, shoaling to 0.
3. Winds variable. Subjected to dust from Santa Ana conditions.
4. Surroundings: The industry is mostly Todd Shipyards, due east, and Harbor Precast Company due north of the station. Several large vessels are permanently moored in this area. There may be fresh water fun-off down a ravine to the west. Boat traffic is restricted to shallow draft vessels. An oil disposal site was operated on grounds to the north, and may have caused seepage.
5. Latitude: 33° 45' 16"; Longitude: 118° 17' 11"

C-6.
1. Located at the NE corner of West Basin.
2. Depth approximately 35 feet.
3. Winds variable.
4. Surroundings: Industry is mostly shipping. Sun Lumber Yard is located to the NW approximately ¼ mile. An outfall of cooling water is present, from the Los Angeles Department of Water and Power and a discharge from Collier Carbon and Chemical Corporation. Boat traffic is mostly freighters and cargo container ships. Bonita have been sighted in this area occasionally.
5. Latitude: 33° 46' 00"; Longitude: 118° 16' 14"

C-7.
1. Located to north end of Slip #1, north of Mormon Island.
2. Depth 35 feet.
3. Winds variable.
4. Surroundings: Near the south end of the slip is the Borax waste products outfall. Discharges from several industries including oil dock facilities are in that area. The water circulation is very restricted in this slip, and at the north end there are Harbor Department docks, and moored boats.
5. Latitude: 33° 45' 44"; Longitude: 118° 15' 55"

C-8.
1. Located at slip #5 adjacent to Berth 185.
2. Depth approximately 35 feet.
3. Winds variable due to the buildings, except for Santa Ana winds, which blow from the north and NE with minimal obstruction.
4. The traffic is industrial, including tankers, offloading cocoanut oil or similar cargo at Berth 187. There have been cargo and fuel spills in this area. The USC Marine Facility dock is located at Berth 187.
5. Latitude: 33^{o} 45' 57"; Longitude: 118^{o} 15' 34"

C-9.
1. Located adjacent to Berth 191 in East Turning Basin.
2. Depth approximately 36 feet.
3. Wind from the SW very much diminished compared to the outer harbor.
4. Surroundings: Raw sewage may come from the marinas near this location. There is extensive boat traffic (freighters and tankers). A Union Oil tank farm is located to the south and the metal reclamation area is adjacent to the Union Oil dock. Freshwater and industrial wastes from Dominguez Channel may affect this area.
5. Latitude: 33^{o} 45' 36"; Longitude: 118^{o} 15' 29"

C-10.
1. Located in the southern edge of the East Turning Basin.
2. Depth about 38 feet.
3. Winds from the SW are much diminished as compared to the outer harbor.
4. Surroundings: Freighter and small boat traffic occurs here. There is a metal reclamation depot directly across the channel from this station. Raw sewage may come from a marina, located to the NE.
5. Latitude: 33^{o} 45' 49"; Longitude: 118^{o} 15' 06"

C-11.
1. Located in Consolidated Slip, adjacent to Berth 200H.
2. Depth 28 feet.
3. Light, variable winds.
4. Surroundings: Freighter traffic occurs at Consolidated Pier, and there is a marina at the NE end of this slip. Drainage from Dominguez Channel may bring fresh water and industrial wastes into this area. Circulation patterns are extremely restricted and freighter traffic may stir up the bottom at times.
5. Latitude: 33^{o} 46' 33"; Longitude: 118^{o} 14' 34"

Long Beach (City) Harbor

The oil islands and Pier J cause surface water movement to eddy to the SE. This allows larger concentrations of phytoplankton organisms to be trapped, perhaps causing the extensive bloom condition at times, known as Red Tides. The Los Angeles River Flood Control Channel affects this area.

D-1.
1. Location approximately ¼ nautical mile due east from the SE corner of Pier J.
2. Depth approximately 50 feet.
3. Wind from the SW unrestricted.
4. Surroundings: Light boat traffic, mainly barges to and from the oil islands off Outer Long Beach.
5. Latitude: 33° 44' 19"; Longitude: 118° 10' 49"

D-2.
1. Located at the mouth of the flood control channel, ½ nautical mile SE of the fixed bridge.
2. Depth 77 feet.
3. Winds variable due to land obstructions.
4. Surroundings: Extensive pleasure boat traffic and water skiing, especially during the summer. Freshwater runoff and debris from the Los Angeles River flood control channel in winter. Extreme red tide conditions sighted in this area in the summer of 1975.
5. Latitude: 33° 45' 24"; Longitude: 118° 11' 33"

D-3.
1. Located approximately 150 meters due south of Island Grissom.
2. Depth about 30 feet.
3. Winds from the SW variable due to land obstruction.
4. Surroundings: Boat traffic is mostly pleasure craft and water taxis to the various islands.
5. Latitude: 33° 45' 17"; Longitude: 118° 10' 52"

D-4.
1. Located about ¼ mile south of Island White.
2. Depth about 32 feet.
3. Winds from the SW unrestricted.
4. Surroundings: Moderate boat traffic, mainly pleasure craft.
5. Latitude: 33° 44' 56"; Longitude: 118° 09' 41"

D-5.
1. Located about ½ nautical mile NE of Island Charley.
2. Depth 25-36 feet.
3. Variable winds.
4. Surroundings: Light to moderate traffic of pleasure craft.
5. Latitude: 33° 44' 31"; Longitude: 118° 07' 53"

D-6.

1. Located ½ nautical mile due S. of Island Charley.
2. Depth about 38 feet.
3. Winds from the SW unobstructed.
4. Surroundings: Light to moderate traffic of ships and pleasure craft. Restricted anchorage.
5. Latitude: 33° 43' 54"; Longitude: 118° 08' 20"

D-7.

1. Located about ½ nautical mile from Island Freeman.
2. Depth 50 feet.
3. Winds unobstructed from the SW.
4. Surroundings: Light to moderate pleasure craft and ship traffic. Restricted anchorage, mooring area.
5. Latitude: 33° 43' 53"; Longitude: 118° 09' 39"

D-8.

1. Located ¼ nautical mile SE of Island Esther.
2. Depth about 37 feet.
3. Winds are from the SW, unobstructed; unprotected by the breakwater.
4. Surroundings: Moderate pleasure craft traffic, plus naval traffic going into Anaheim Bay.
5. Latitude: 33° 42' 56"; Longitude: 118° 06' 31"

D-9.

1. Located approximately ¼ nautical mile SE of entrance to the San Gabriel River channel.
2. Depth about 14 feet.
3. Winds from the SW mostly obstructed due to the SE breakwater at the entrance to Alamitos Bay.
4. Surroundings: There is a thermal discharge from the Haynes Steam Plant, which raises the temperature of the water in the immediate vicinity by 3 to 5 degrees. Extensive bonita found in this area, making it a favorite fishing spot; hence the heavy pleasure craft traffic. Shoaling in this area results in wave action which attracts surfers.
5. Latitude: 33° 44' 04"; Longitude: 118° 07' 04"

BREAKWATER ALGAL/INTERTIDAL SURVEY

Inside Breakwater	Station Definition	Outside Breakwater
H1	33° 42' 14" N 118° 15' 58" W	H7
H2	33° 42' 46" N 118° 14' 16" W	H8
H3	33° 43' 07" N 118° 13' 08" W	H9
H4	33° 43' 23" N 118° 12' 20" W	H10
H5	33° 43' 23" N 118° 09' 07" W	H11
H6	33° 43' 23" N 118° 09' 17" W	H12

EMPLOYEES OR ASSOCIATES OF HARBORS ENVIRONMENTAL PROJECTS 1974-1976

MANAGEMENT BIOLOGISTS

Director: Dorothy F. Soule, Ph.D., Senior Research Scientist, Allan Hancock Foundation, Adjunct Professor of Environmental Engineering, Coordinator of Sea Grant Program; Marine Biology.

Associate Director: Mikihiko Oguri, M.S., Research Fellow, Allan Hancock Foundation; Phytoplankton Ecology, Marine Biology.

Marine Biology/Ecology

Principal Investigators

Bernard C. Abbott, Ph.D., Phytoplankton, Toxicity
Mikihiko Oguri, M.S., Phytoplankton
John Dawson, M.S., Zooplankton
John S. Stephens, Ph.D., Ichthyology
John D. Soule, Ph.D., Settling/Fouling Communities
Dorothy F. Soule, Ph.D., Settling/Fouling Communities
Donald J. Reish, Ph.D., Settling and Benthic Communities
Kristian Fauchald, Ph.D., Benthic Biology and Bioassay
Sr. Damian Marie Juge, Ph.D., Microbiology

Project Managers

Gary Brewer, Ph.D., Ichthyology, Bioassay
Dilworth Chamberlain, Ph.D., Ichthyology, Bioassay
Ray Emerson, Ph.D., Benthic Biology, Bioassay
Robert Smith, Ph.D., Benthic Biology, Computer Analysis
Thomas Kauwling, Benthic Biology
John McConaugha, Bioassay, Benthic Biology
Michael Martin, Benthic Biology, Settling/Fouling Communities
Robert Osborn, Benthic Biology
Lisa Reish, Settling/Fouling Communities
Gail Griest, Microbiology

Staff

Settling/Fouling Communities

Karen Green
Steven Kimmel
Michael Martin
James McSweeney
Fred Piltz
Paul Pyle
Lisa Reish
Richard Ware

Benthic Biology

Donna Anderson
Julie Anderson
Juanda Anderson
Valerie Anderson
Frank Chin
Joanne Doi
Julia Dragojevic
Eileen Drake

Staff (continued)

Charlyn Hawelu
Cynthia Hunter
Joan Jacob
Yvonne Lau
Kenneth Meyer
Edward Moy
Eri Nitta
Peggy O'Donnell
Fred Piltz
John Shisko
James Shubsda
Ismay Stanley
Agnes Tomita
Richard Ware
Hope Watkins
Sue Williams
Christine Yonai

Ichthyology

Jay Carroll
John Helle
S. Ishikawa
Catherine Kusick
Karl Lyde
Scott Ralston
Steve Subber
Catherine Terry

Zooplankton

Diana Hamlet
Richard Hammer
Geraldine Knatz
Wayne Kuwahara

Microbiology

Maria Appleman, Ph.D.
Max Fields
Joan Frey, Ph.D.
Madelon Halula
Judith Himmel
Mary Ann Kasnicka
Sally Kasnicka
Mary K. O'Neil
Vivian Pai

Phytoplankton and Productivity

Janice Beeler
Manjit Grewall, Ph.D.
Steven Kimmel
Gregory Morey-Gaines
Stanley Wojcik

Environmental Engineering/Geochemistry

Principal Investigator

K.Y. Chen, Ph.D., Environmental Engineering, Geochemistry

Staff

Andre Anderson
Edith Bergary
Lata Bhatt
Nick Brovka
W.W. Choi
Y.C. Chuang
Bert Eichenberger
Nancy Folks
S.K. Gupta
Miroslav Knezevic
R. Addis Lockwood
J.F.S. Lu
T.P. Pan
Pashmin Pathak
Amancio A. Sycip
Y.Y. Tsai
C.C. Wang

Oceanography

Project Manager

Kendal Robinson, Oceanography, Geology

Staff

Bruce Adams
Cary Dritz
Ben Hamilton
Steven Kimmel
Wayne Kuwahara
Monte Lew
James McSweeney
Gene Mummert
Steve Odenback
Harold Porath
Paul Pyle
David Schomisch
Jan Six

Nutrient Chemistry

Project Manager

Hester Kobayashi

Staff

Bruce Adams
Steven Kimmel
James McSweeney
Steve Odenback
Paul Pyle

Biological Consultants

Ornithology

Elizabeth Copper
John W. Hardy, Ph.D.
Dennis M. Power, Ph.D.
Thomas Webber
Robert Copper

Marine Biology

Sharon Christopherson
Robert Given, Ph.D.
Penny Morris, Ph.D.
Richard Pieper, Ph.D.

Algology

Nancy L. Nicholson, Ph.D.
Robert Setzer

Intertidal Surveys

Dale Straughan, Ph.D.
Mary Patterson, M.S.

Terrestrial Botany

Ethan D. Churchill, Ph.D.

Abiotic Modelling

John Stanley-Miller, Ph.D.

Biotic Modelling

Patricia Kremer, Ph.D.

Computer Analysis

Program Managers

Nicholas Condap, Programming and Data Processing
John W. McDonald, Geography and Computer Mapping
Robert W. Smith, Computer Analysis

Staff

Eduardo Ceballos	Ann Newman
Kathleen Condap	Diane Parker
Donnilee Ellis	Joan Pearce
Ben Hamilton	Irene Phillips
James McSweeney	David Schomisch
Steve Miller	Ismay Stanley

Office Administration

Ruth A. Steiger	Gene Mummert

Graphics/Illustration

Elizabeth Goldberg	Catherine M. Link

Office Technical Staff

Betty Bryant	Donna Kinser
Charles Greaves	Catherine Link
Susan Harrison	Julie Thompson
Kaoru O. Kendis	Ismay Stanley
Randall Kendis	

Marine Technicians

Bruce Adams	Gene Mummert
Eduardo Ceballos	Steve Odenback
Dan Dabelstein	Robert Osborn
Cary Dritz	Nancy Poquette
Frank Edmands	Harold Porath
Ben Hamilton	Paul Pyle
Mark Hooper	David Schomisch
Steven Kimmel	Mary Ann Scott
Wayne Kuwahara	Jan Six
Monte Lew	Mary Smith
Michael Martin	Elizabeth Swann
James McSweeney	Billie Yeaman

Chapter 2

ABIOTIC CHARACTERIZATION OF THE HARBORS

ABIOTIC CHARACTERIZATION OF THE HARBORS

OCEANOGRAPHY

Surface currents off the California coast south of Point Conception consist primarily of the southeastward flowing California Current and one or more counterclockwise gyres. This results in a counter-current flowing northwestward near the coast, at least part of the time. Subsurface currents have a southerly origin, and vary greatly in direction, velocity, and flow. These factors influence the oceanography and water quality of the Los Angeles-Long Beach Harbors area.

Less has been documented about the smaller gyres, eddies and fluctuations which occur along the shores, in harbors and around the channel islands. Jones (1971) reviewed the existing literature on the southern California bight, and Soule (1974) summarized the major eastern regimes and their thermal characteristics.

Several field studies of currents and circulation in the harbor have been published. Soule and Oguri (1972), and Robinson and Porath (1974), reported on drogue and current meter studies in the outer harbor. The Army Engineer Waterways Experiment Station measured currents and seich (Pickett, et al., 1975) prior to construction of the scale model of the entire harbor, from which a number of studies have come (McAnally, 1975).

Circulation and Flushing

Currents in the harbor are determined by the boundary conditions of shallow water and the configuration of the basin, with the driving energy supplied by tides and wind. Except during and after winter season rains, run-off is insufficient to influence the currents greatly. A seasonal thermocline sometimes appears in the harbor during the warm months of the year, permitting a decoupling of the surface waters, where tidal effects would dominate. The above field studies were carried out during June and July of 1972 and 1973, months when a thermocline might be expected.

Locally there are two unequal tides per day with a mean range of 1.2 meters (3.8 feet) and a maximum of about 3 meters (10 feet). Tidally-generated surface currents, reported by McAnally (1975), are typically low, reaching a maximum of 0.3 meters (1 foot) per second during spring tides and 0.15 meters (0.5 foot) per second during a neap tide. Robinson and Porath (1974) reported subsurface currents falling in the range of 0.05 meters (0.17 foot) to 0.1 meters (0.34 foot) per second at 3.6 meters (12 feet), and at 4.6 meters (15 feet), with the average velocity of the bottom currents at one station measuring 0.024 meters (0.08 foot) per second.

Tidal discharge volumes calculated by McAnally (1975) into and out of the harbor show a net inward flow through Angels Gate and Queens Gate and a net outward flow through the passage between the eastern end of the Long Beach Breakwater and Alamitos Bay. The data presented indicate a net eastward flow of water within the harbor. This emphasizes the importance of Queens Gate as a source of "new" rather than recirculated water for the area east of Pier J in Long Beach, and the influence of the waters of outer Los Angeles-Long Beach Harbors on that area.

The nodal point for tidal circulation in the Long Beach Channel-Cerritos Channel-Los Angeles Main Channel appears to be in the Cerritos Channel, most likely near the constriction in this channel at the site of the drawbridge and lift bridge. Current velocities are low through this series of channels, with the lowest velocities occurring in the Cerritos Channel. There appears to be a net flow toward the west in Cerritos Channel. Currents in the dead-end slips are very low. Mixing is largely due to advection and stirring by ships.

The dominant feature in the outer harbor is a large clockwise surface gyre, shown in Figures 2.1 and 2.2. The two field studied, by Soule and Oguri (1972) and Robinson and Porath (1974), show that subsurface currents can reverse this direction. These gyres persist on both rising and falling tides. A smaller counterclockwise gyre to the north of the San Pedro Breakwater is less persistent. The report by McAnally (1975), the only one of the three studies that covers the basin east of Pier J, Long Beach, indicates the presence of a series of opposing gyres and eddies within the basin. The tidally generated circulation patterns reported by McAnally (1975) for a spring tide condition are shown in Figures 2.1 and 2.2. The presence of the features discussed above are evident, particularly the large clockwise gyre in the outer harbor. Reish (1959) published a similar diagram of the surface circulation in the outer harbor as observed prior to the construction of Pier J, redrawn from his data (Figure 2.3). The dominant gyre noted in the recent studies above, was absent in the earlier Reish study, suggesting that the addition of Pier's F, G, and J have modified existing circulation.

Winds influencing the harbor are usually of low velocity and offshore during the night and early morning. An onshore sea breeze of somewhat greater velocity dominates in the afternoon. In late summer or early fall, strong onshore east or northeast day winds, referred to locally as Santa Ana winds, often occur and persist for two to three days. Winter storms, usually easterly to southeasterly, also are factors in wind-induced currents in the harbor. None of the three studies of circulation included effects of either Santa Ana winds or winter storms. Currents of inner harbor areas are less subject to wind induction than those of the outer areas, because of the lack of fetch and shielding effect of surrounding structures.

Waves

There are three types of waves that affect planning, design and environmental impact assessment: 1) swell, or waves arriving from a distant source; 2) sea, or waves generated by wind in nearby regions; and 3) long period waves, or those responsible for long period surging action in harbors.

Long period wave data are a very important element in the design because as vessel size increases, wave surge will be determined primarily by relatively long period waves. Wilson, et al. (1968) have discussed historical events associated with surge phenomena in San Pedro Bay. Sparsely observed long period wave energy was compared with theoretically calculated seiche (or surging) periods of the outer harbor and certain slips and basins. Surging periods ranging from 1 minute to 1.33 hours were found by many investigations. Munk, et al. (1963) made extensive long period wave measurements at San Clemente Island and found that the dominant wave energy flies in the waves with periods ranging from 12 to 20 seconds.

Measurements at locations outside and inside the San Pedro Breakwater by Lee and Walther (1974) indicated that the predominant wave period occurs at 16 to 17 seconds. At this wave period the wave transmission coefficient (the transmitted wave amplitude divided by the incident wave amplitude) is 0.3. Thus, a wave 1 meter (3.3 feet) high outside the breakwater will be a 0.3 meter (1 foot) wave inside the breakwater.

PHYSICO-CHEMICAL PARAMETERS

The California State and Regional Water Pollution Control Boards (now the Water Quality Control Boards) were established in 1949. The Los Angeles-Long Beach Harbor Pollution Committee was established in 1951, and subsequently a monthly monitoring program was instituted for sulfides, dissolved oxygen, and temperature. Records from 17 Los Angeles Harbor stations and 13 Long Beach area stations furnish a long term picture of the harbor waters prior to and during the clean-up efforts that followed (Los Angeles Regional Water Quality Control Board, 1969). Since the non-biological (abiotic) characteristics of the harbor largely determine the nature of its biological characteristics, influencing the species composition, numbers and distribution of the biota, these parameters are extremely important to the harbor ecology.

Temperature

Temperature regimes differ considerably from year to year in the southern California area (Soule, 1974), due in part to the variability in extent and duration of warm water intrusion by the northerly flow of the Davidson current. Variations in wind, clouds, fog, rainfall, and air temperature also affect local water temperatures. The thermal structure in turn affects

the species numbers and kinds that occur in the harbor in any one season or year. The high temperatures for a particular day in a particular year are lower than in the lows of the same day in other years (Soule, 1974; Soule and Oguri, 1976). Hence sampling and measurement for only a single date, season, or year may give a very misleading picture of the total environment. Mean temperatures illustrate annual regimes, but the extremes furnish the limits of tolerance for various species.

The lowest temperatures observed in the harbor in recent years were in December, 1971, when the surface temperature fell to 9.5° C (49.1° F) and the bottom was 8.2° C (46.8° F) at Angels Gate. Also, in April, 1973, the surface temperature reached 11.0° C (51.8° F) and the bottom 8.2° C (46.8° F). At those same times, bottom temperatures immediately inside the entrance also fell below 9° C, and at other stations were about 11° C. Even in West Basin, Los Angeles, at the Harbor Power Plant, where the surface temperature was 15.9° C, the bottom temperature was 11.5° C, showing the extent of cold water intrusion (Soule and Oguri, 1974).

The maximum temperatures found in the harbor are in the shallower inner slips with reduced circulation, and the peaks occur at times different from those of the peaks in the outside waters, probably reflecting retention time. Again using Angels Gate sea buoy for earlier data, in September, 1971, the surface measured 21.2° C (70.2° F) and the bottom 15° C (59° F). West Basin (Los Angeles, A8) in that summer showed 22.1° C in July, 25.8° C in August, 21.5° C in September, and 22° C in October, indicating the differences in the inner harbor. In 1972, the peak A1 sea buoy temperatures occurred in June, with 18.8° C (65.8° F), and in September, with 19.6° C. In 1973, the peak occurred at A1 in July, with 18.4° C. West Basin (Los Angeles) peaked at 26° C in July, 1972, but in 1973 the highs were June and October, with 22° C.

Dissolved Oxygen

Dissolved oxygen (DO) levels in surface waters are used by regulatory agencies to measure water quality, and 5 ppm has been designated as the minimum level for acceptable environmental quality; 9 ppm is defined here as a representative theoretical saturation level in sea water. (The actual saturation level varies somewhat depending on salinity and temperature.) Records outside Angels Gate show that surface dissolved oxygen fell to 3 ppm in November, 1971; at the same time the DO was below 3 ppm in the outer harbor. The DO also dropped to about 5 ppm in March, 1972 and November, 1972. Areas with lower circulation or high waste loads show low readings much more frequently.

Dissolved oxygen concentration in the waters is due to a balance between those processes that add oxygen and those that deplete it. Algal photosynthesis may provide up to 90% of the

dissolved oxygen. Surface mixing and transport into the area add to the supply. Processes that deplete the DO include the respiratory demands of the biota, Biological Oxygen Demand (BOD), plus chemical and physical demands due to oxidation (COD and IOD), as well as transport out of the area. Surface DO levels in the harbor vary greatly (Soule and Oguri, 1974; 1976).

Readings reached maxima in excess of 16 ppm at times. High values occurred during the warm months and were associated with intense phytoplankton blooms that occurred throughout the harbor. Low values occurred during the cooler months when phytoplankton populations were lowest. Vertical distribution of DO showed patterns of maxima occurring at subsurface depths in the winter and at the surface in the warmer months. Minima usually occurred at or near the bottom of the water column during the warm months. This suggests that the freshwater effluents and run-off in winter are lower in dissolved oxygen than the underlying sea water. During the summer, photosynthetic activity of the phytoplankton oxygenates the surface waters rapidly, offsetting the oxygen demand of the effluents. The deeper waters are at times isolated from the oxygen-rich surface waters by the formation of thermoclines and the DO is not renewed rapidly enough to offset the demands placed on it.

In 1971, bloom conditions, defined arbitrarily by readings above 9 ppm, occurred outside the harbor in September; in 1972, blooms occurred in April, May, June, August, September, November, and December. Higher temperature peaks occurred in 1971 than in 1972. Temperatures remained warm longer in 1973 than in 1974, but the peak was higher in 1974. A bloom occurred in March, 1973, outside Angels Gate, but the bloom (high oxygen) occurred in April and May at Queens Gate. In 1974, blooms occurred in June, September, and November. The D stations show patchy blooms for most of the year. In 1973, monitoring began in March under bloom conditions, which extended through September, with an April peak. In 1974, blooms occurred in January, started again in April, and extended through November. The arbitrary designation of bloom conditions by oxygen reading requires further investigation to document species involved and other conditions which could lead to higher readings. Mixing associated with maximum tides and storms accounts for some occurrences.

<u>Salinity</u>

Salinities in the harbor were measured in 1971-72 in outer Los Angeles Harbor by remote probe sensor (conductivity converted to salinity by computer program). Extremes in salinity values found in the entire harbor area in 1973 ranged from 23.15 to 37.83 ppt with highs at the mouth of the San Gabriel River and at the Alamitos Power Plant. Two other high salinity pools occurred near the large gyre area encompassing stations

A2, A3, A7, A11, and A12 in the outer harbor. The frequency distributions show that the commonest salinity range is between 30.00 and 34.21 ppt. Salinities vary according to rainfall, run-off, effluents and evaporation.

A salinity layering occurred at B2 and B3 in January through April of 1973, indicating a freshwater lens outside the breakwater, as well as inside the harbor. The outer harbor waters are usually well mixed, while inner waters show a gradient with depth. In January, 1973, a single storm dropped about nine inches of rainfall of the Los Angeles Basin and the readings indicated that the freshwater persisted for some time on the surface.

In 1973, mean salinities in some areas of the harbors were approximately one part per thousand higher than in 1974. This was probably due to the reduction in discharge into the harbor of oil field brines following orders from the Regional Water Quality Control Board. Surface salinities ranged from a low of about 31 ‰ to a high of about 33.9 ‰ during the two years. The deeper waters showed somewhat higher salinity values, reflecting the influence of freshwater run-off.

pH

The pH of the waters was measured by remote probe at A stations in 1971-72 and throughout the harbor in 1973 and 1974. These readings showed a tendency at times to follow the same patterns as the variations in dissolved oxygen, but in some instances the patterns appeared to be unrelated (Soule and Oguri, 1976). The higher pH values were found usually in the warm months and at the surface. Lower values were generally found in cool months or near the bottom. Values below 7 or in excess of 8.5 seldom occurred. The relationship between DO and pH has not been statistically tested but was noncritically observed in the data reported for the area.

In the D stations, pH readings varied widely from month to month and did not coincide with the oxygen bloom peaks. This may be related to the organic load from the Los Angeles River, to the oil islands, or to the thermal effluent at Alamitos.

Light Transmittance

The amount of light available to the phytoplankton in harbor waters is determined by ambient sunlight and by weather such as cover and fog. Light penetration is controlled by turbidity in the water, sediment suspension, turbid waste products, or density of phytoplankton. Turbidity was measured by a Transmissometer. In 1972, the mean values of percent transmission in the harbor areas ranged between 63.13 and 85.82 at metered stations. In 1974, the range was from 43.12 to 79.37, perhaps in part reflecting the increased phytoplankton blooms as evidenced by the high oxygen readings.

COMPUTER ANALYSIS

Although there are two ports and several jurisdictions for the harbors in San Pedro Bay, physically, chemically, and biologically they are part of a single system and are jointly referred to as "the harbor." The physical and chemical characterization of the harbors has in the past been largely subjective and qualitative in character. Studies were insufficient in scope, in area covered, in parameters measured, and in time. Thus, extrapolation was difficult, although some of the pertinent parameters involved in the abiotic environment are readily apparent. The contribution of those parameters to the total environment may in some cases be conjectured.

Data collected during the present investigations offers a sufficient quantity and scope to permit development of a more objective and quantified consideration of the environment. There are a number of differences among the stations in the study. However, the standardized measurement of multiple parameters showed that stations could be classified into converging groups. This information could be used, therefore, to separate the stations into groups with similar characteristics. The analytical methods used to classify the abiotic parameters and to characterize groups of stations or areas throughout the harbor are described on the following pages.

It is important to note that no single classification of abiotic groups and biotic groups is adequate to represent all harbor stations at all times for all parameters. However, the majority of the groupings developed showed the separation of outer harbor stations from channel stations and from dead-end slips.

MATERIALS AND METHODS

Two analyses were performed; the first includes variables measured near the water surface, and the second includes bottom-water and sediment measurements.

Surface Data. The monthly measurements of dissolved oxygen (DO), pH, percent transmission, ammonia, phosphate, nitrate, nitrite, salinity, and temperature, for the year 1974, were used to calculate the mean value for each station. In the case of temperature and salinity, the standard deviation was used as a measure of variability, and the oxygen and pH minima were also included.

Bottom Data. The monthly measurements of temperature, DO, pH, and percent transmission of the bottom water for the year 1973 were used to calculate means and standard deviations (salinity and temperature) or minima (oxygen and pH). Information concerning the sediment variables used as a basis for classification is contained in the section of this report on benthic biota.

Methods of Analysis. Prior to the classification of the abiotic data, the variables were standardized to a common scale. For this purpose each variable was centered by its mean and divided by its standard deviation. If the distribution of the raw values of a variable was distinctly skewed, the values were transformed by a log prior to the standardization. Since centering by the mean produces negative values, the Bray-Curtis measure used in the biotic classification is inappropriate. Instead the Euclidean distance measure was used, whereby

$$D_{ij} = \sqrt{\sum_{k=1}^{n} (X_{ki} - X_{kj})^2}.$$

D_{ij} is the distance between samples i and j, X_{ki} is the standardized value of variable k in sample i, and n is the number of variables.

If one wishes to classify the variables, certain modifications are necessary. This is due to the fact that negatively correlated variables will be separated by a relatively large distance and will not cluster. Significant negative correlations are just as important as positive correlations in this type of study.

When the data are centered and standardized by the variable mean and standard deviation respectively, the distance between two variables and their intercorrelation is related as follows:

$$D_{ij} \quad \sqrt{2\,(1 - R_{ij})}$$

where R_{ij} is the correlation between the variables i and j (Anderson, 1971). To remove distance differences due only to the sign of the correlation, the calculations are modified by using the absolute value of R.

Once the distances were calculated, they were standardized to a 100 point scale for convenience, and then used to build a dendrogram as in the biotic classification. Two-way tables were also used to show the relationships between the

station (sample) groups and the variable groups.

The results of a classification based on abiotic variables should be interpreted with caution. First, in the classification of stations, each environment factor will not necessarily have equal weight. Several of the measured variables may be correlated with the same environmental factor; such a factor would receive more weight in the analysis than would another factor which related to only one or a few of the measured variables. Secondly, such an analysis is performed independent of the biotic data. The weighting of the environmental factors is dependent on which variables are measured and their interocrrelations. Conclusions concerning the biota are unwarranted without further analysis.

RESULTS

Surface Data

Figure 2.4 shows the classification of the stations by means of a summary matrix, and Figure 2.5 shows the location of the stations in the various groups. Figure 2.6 and Table 2.1 contain the variable classification and two-way table, respectively. From an examination of the two-way table, the following general patterns become evident:

Group 1. Stations B2, B5, and B7 in Port of Long Beach inner channels, and A8 at the entrance to the Los Angeles main channel. These stations were distinguished principally by the least amount of standard deviations from the means of the parameters, as seen in the Two-Way Table.

Group 2. Stations B1, B3, B4, B8, B9, B10 and B11 in Port of Long Beach outer harbor or main channel, and A1 outside Angels Gate of Los Angeles Harbor. These stations showed larger standard deviations from the means, with higher means and minima for dissolved oxygen, salinity, pH, and percent light transmittance, but with negative deviations in means and minima for ammonia, phsophate, nitrate, and nitrite.

Group 3. Outer Long Beach City Harbor stations D1, D4, D5, D6 and D7. These areas showed higher standard deviations in BOD, DO, pH, and percent light transmittance, but greater negative deviations in salinity and temperature were recorded than those in Group 2 stations.

Group 4. Outer Los Angeles Harbor A Stations. This area is characterized by greater standard deviations in salinity and nitrates but negative deviations in mean salinities and BOD.

Group 5. Los Angeles Harbor main channel and inner harbor slips, and inner Long Beach station B6. These are characterized by greater negative standard deviations in minima and means in DO and pH. Higher standard deviations in mean temperature were recorded. Variability was shown in nutrients, salinities, and percent light transmittance.

Group 6. Stations D2 and D3 at the mouth of the Los Angeles River. This area showed greater variability in ranges of standard deviations in all parameters.

The area of the Port of Long Beach that would be affected by implementation of the General Plan had good water quality at the time of the study, on the basis of surface abiotic parameters.

Bottom Data

The results of the classifications are shown in Figures 2.7 to 2.9 and Table 2.2. This analysis is heavily weighted in favor of the variables which could be related to a depositional environment. A weak current in an area plus a source of materials leads to a situation where fine sediment will accumulate along with heavy metals, organics, oil and grease and pesticides. Some of these materials will make demands on the local oxygen supply, and since the rate of oxygen input from elsewhere is already limited by the weak currents, low oxygen conditions will prevail and lead to a high sulfide, IOD and COD conditions. The variables in the first three variable groups are related to this factor.

Since so many of the measured variables are correlated with this one factor, related to deposition, the station groups defined will reflect this. From the two-way table (Table 2.2), it can be seen that the most extreme depositional-type environment is at stations in Group V. These stations are almost all at the dead ends of slips, where the currents would be minimal. Group VI is similar to Group V. The differences observed are no doubt due to the fact that Group VI is near the mouth of the Los Angeles River. Less extreme along these lines is Group IV, which contains stations in outer Los Angeles Harbor, Fish Harbor and the lower Main Channel. Group II, which is mostly made up of sites in outer Long Beach Harbor, was generally characterized by moderate to mixed levels of depositionally related variables. Groups I and VII are in areas with relatively stronger currents, as indicated by the coarser sediment and lower levels of the depositionally related variables. Group III, consisting of only station C10, shows fine sediment but other of the depositionally related variables are average.

As mentioned, this analysis is weighted in favor of the depositionally related variables. Because of this, the other variables (i.e., those in variable Group V) are not as consistently or as well defined in the groups delimited.

DISCUSSION

Overall, the patterns shown by the surface and benthic abiotic parameters reflect the importance of currents and flushing. The relatively limited water turnover in the waters of the channel, along with the input of various materials, is probably the cause of the consistently lower levels of oxygen, higher levels of nutrients and higher temperatures in the area. On the bottom the currents in the vicinity of the dead ends of slips would be minimal and this is where very heavy deposits of heavy metals, pesticides, and organics are found, along with very low levels of oxygen and the associated COD, IOD, and sulfide levels.

Mixing occurs, due to ship traffic, resuspending the sediment. Wind-driven mixing also occurs in the outer harbor, but is less important in protected channels and slips. Seasonal thermal inversions also cause stirring and turnover of waters, with resuspension of sediments. In the spring and fall, surface waters may be chilled rather rapidly, while subsurface waters remain warmer. Cold waters sink, and warm waters rise, bringing bottom waters and sediments to the surface. This phenomenon is common in lakes, but occurs in marine waters of limited circulation.

This situation is in contrast to the area around A7 and A11, which is in the vicinity of a sewage outfall and cannery effluents. The currents in this area are evidently sufficient to prevent a large build-up of toxic materials and to prevent continual low oxygen conditions. Stations D2 and D3 are also in the vicinity of an input of materials (the Los Angeles River). Evidently the bottom currents here are not sufficient to prevent a considerable build-up in the area. Both these areas (effluent area and river mouth), however, show high levels of BOD and turbid waters (see Group VI, Table 2.2).

ABIOTIC-BIOTIC CHARACTERIZATIONS

The biotic characterizations of the harbor which are discussed in the subsequent chapters of the present volumes reflect the abiotic conditions of the harbor. The environmental quality of the harbor is more easily observed and expressed in measurable abiotic parameters than it is in the biological properties. However, the biological properties are those which ultimately affect the public in terms of recreational contact, fouling organisms, fisheries, resources, and esthetics.

An example of the interaction between the abiotic and biotic parameters is presented in Figure 2.7, which shows the theoretical oxygen budget of the harbor. Since all life in the harbor is dependent upon available dissolved oxygen, the production of oxygen by phytoplankton and the solution of oxygen by aeration are the major sources for the biota. In

turn, chemical interactions, degradation of organic wastes and metabolism of organisms represent oxygen demands which deplete the dissolved oxygen content and may reduce water quality.

Achieving a harbor that is efficiently functional to handle the prime responsibilities of trade and transport and yet maintain an acceptable quality of environment is a management responsibility that depends on developing further understanding and quantification of abiotic-biotic interactions.

Computer analysis of data and computer mapping offer some new and inovative techniques for correlating data and presenting visual evidence of relationships or distribution patterns. In the following chapters, some or all of the techniques listed have been employed.

IMPACT

The present patterns of circulation and flushing in the harbors will be drastically altered by the proposed changes in the complete master plans for both harbors.

The landfills and the dredging to deepen channels will most likely result in a decreased low water volume and a marked decreased in the tidal prism. The effect of this is a net reduction in the flushing rate of the harbors and a corresponding increase in the residence time of water within the breakwater.

Circulation in the outer harbor area is presently dominated by a single large gyre between the middle breakwater and Terminal Island. This will disappear due to landfill and will be replaced by smaller gyres in the slips and basins formed by the proposed landfill. Tests in the WES hydraulic model at Vicksburg, Mississippi, indicate that the direction of flow in the inner Harbor areas will be reversed, with a net flow from Los Angeles Harbor to Long Beach Harbor around the northern side of Terminal Island.

The construction of dead-end slips will create pockets of extremely low currents and in these areas the water may approach stagnation, as is the case in the dead-end slips with the present harbor configuration.

The deepening of the channels can promote formation of thermoclines or other density discontinuities. This suggests that current patterns different from those described above can develop. Such differences between subsurface currents and surface currents were reported by Soule and Oguri (1972) and Robinson and Porath (1974) in the outer Harbor.

Wind-induced waves will be reduced in the new configuration since the fetch that presently exists will be sharply reduced. Long period waves have not been studied for the proposed configuration in the model, but the construction of new basins and slips in close proximity creates increased patterns of possible resonance which may be of significance.

LITERATURE CITED

Allan Hancock Foundation. 1975. Environmental investigations and analyses for Los Angeles-Long Beach Harbor. Report to the U.S.Army Corps of Engineers. Contract No. DACWD 9-73-0112. D.F.Soule and M.Oguri, eds. 552 p.

Chen, K.Y. and J.C.S.Lu. 1974. Sediment compositions in Los Angeles-Long Beach Harbors and San Pedro Basin. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 7. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. 177 p.

Environmental Quality Analysts/Marine Biological Consultants. 1975. Marine monitoring studies. Long Beach Generating Station, Southern California Edison Company. 1974 Annual Report.

Jones, J.H. 1971. General circulation and water characteristics of the southern California bight. So. Calif. Coast. Water Res. Proj. 37 p.

Los Angeles Regional Water Quality Board. 1969. Review of information pertinent to Los Angeles-Long Beach Harbor and Dominguez Channel.

McAnally, W.H., Jr. 1975. Los Angeles and Long Beach Harbors model study. Report 5. Tidal verification and circulation tests. Tech. Rpt. H-75-4. U.S.Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Oguri, M., D.F.Soule, D.M.Juge, and B.C.Abbott. 1975. Red tides in the Los Angeles-Long Beach Harbor. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 8. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 109-119.

Pickett, E.B., D.L.Durham and W.H.McAnally. 1975. Los Angeles and Long Beach Harbors model study. Report 1. Prototype data acquisition and observations. Tech. Rpt. H-75-4. U.S.Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Reish, D.J. 1959. An ecological study of pollution is Los Angeles-Long Beach Harbors, California. Allan Hancock Foundation Publ. Occas. Paper No. 22. 119 p.

Robinson, K. and H.Porath. 1974. Current measurements in outer Los Angeles Harbor. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 6. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles.

Soule, D.F. 1974. Thermal effects and San Pedro Bay. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 3. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. 20 p.

Soule, D. and M.Oguri. 1972. Circulation patterns in Los Angeles-Long Beach Harbor. Drogue study atlas and data report. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 1. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles.

Soule, D. and M.Oguri. 1974. Temperature, salinity, oxygen, and pH in outer Los Angeles Harbor. Data Report. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 5. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. 76 p.

Soule, D.F. and M.Oguri. 1976. Physical water quality in the Long Beach Harbor area. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 10. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. 173 p.

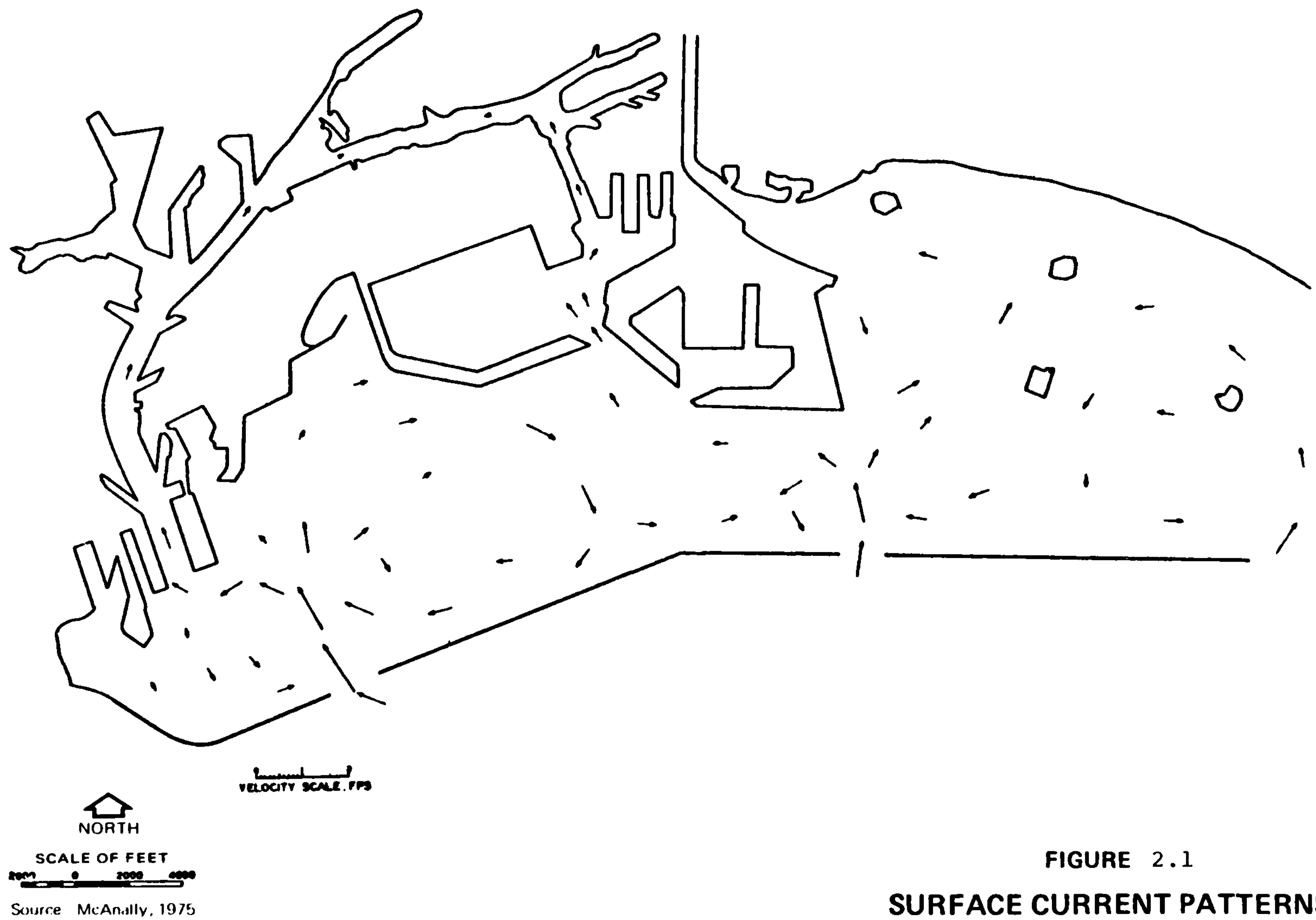
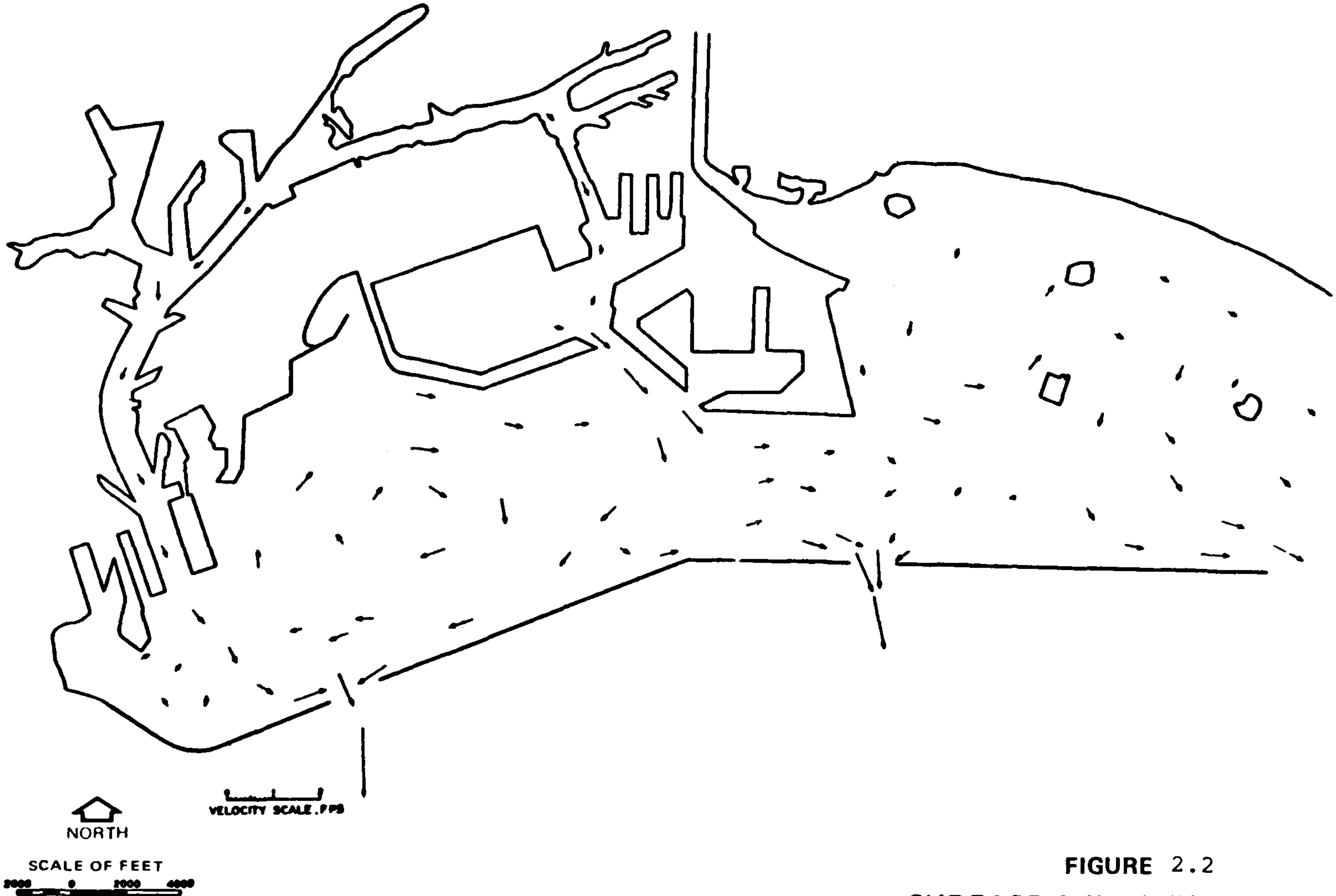


FIGURE 2.1

SURFACE CURRENT PATTERNS

Base Test, Spring Tide Hour 6



Source McAnally, 1975

FIGURE 2.2
SURFACE CURRENT PATTERNS
Base Test, Spring Tide Hour 13

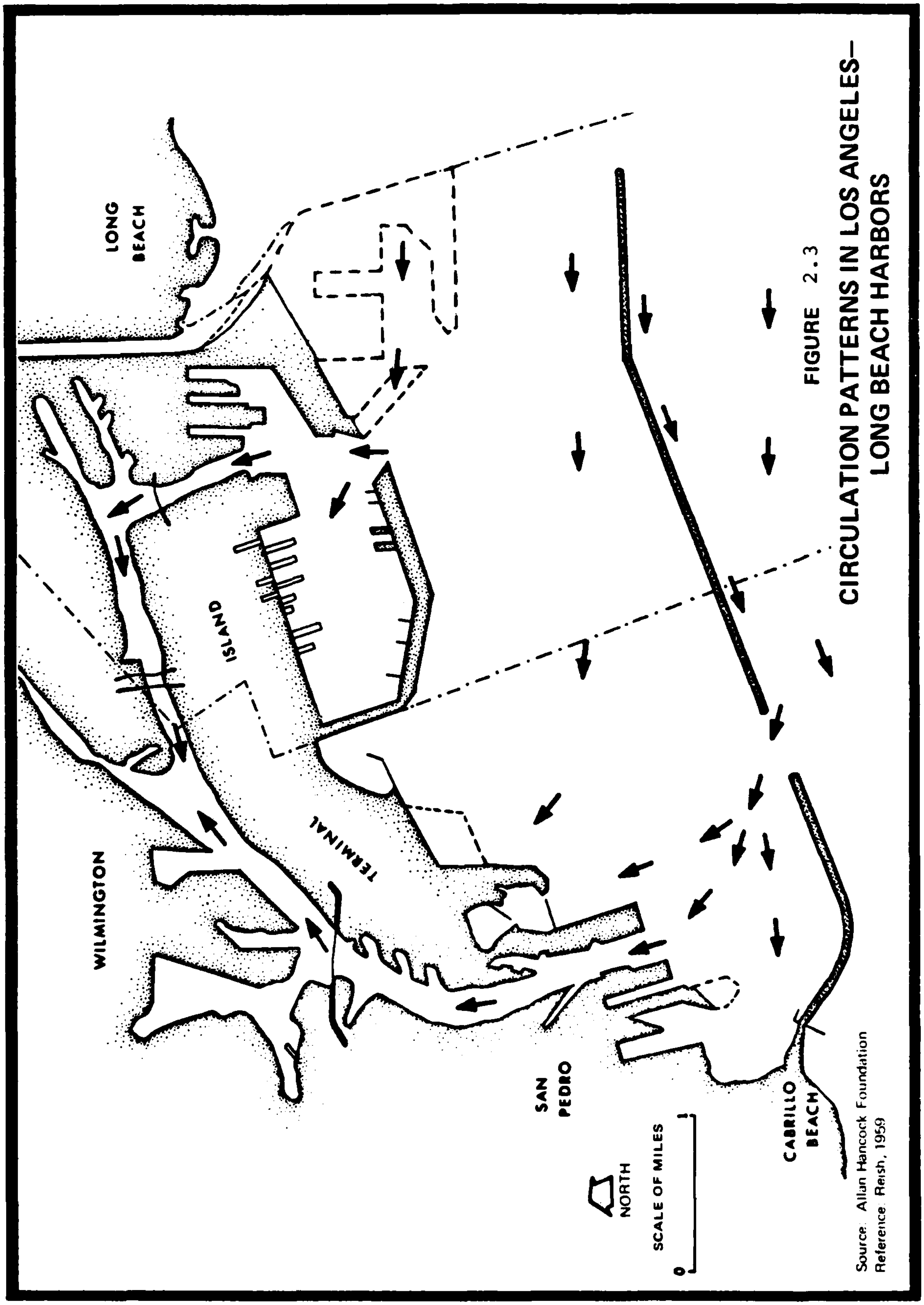
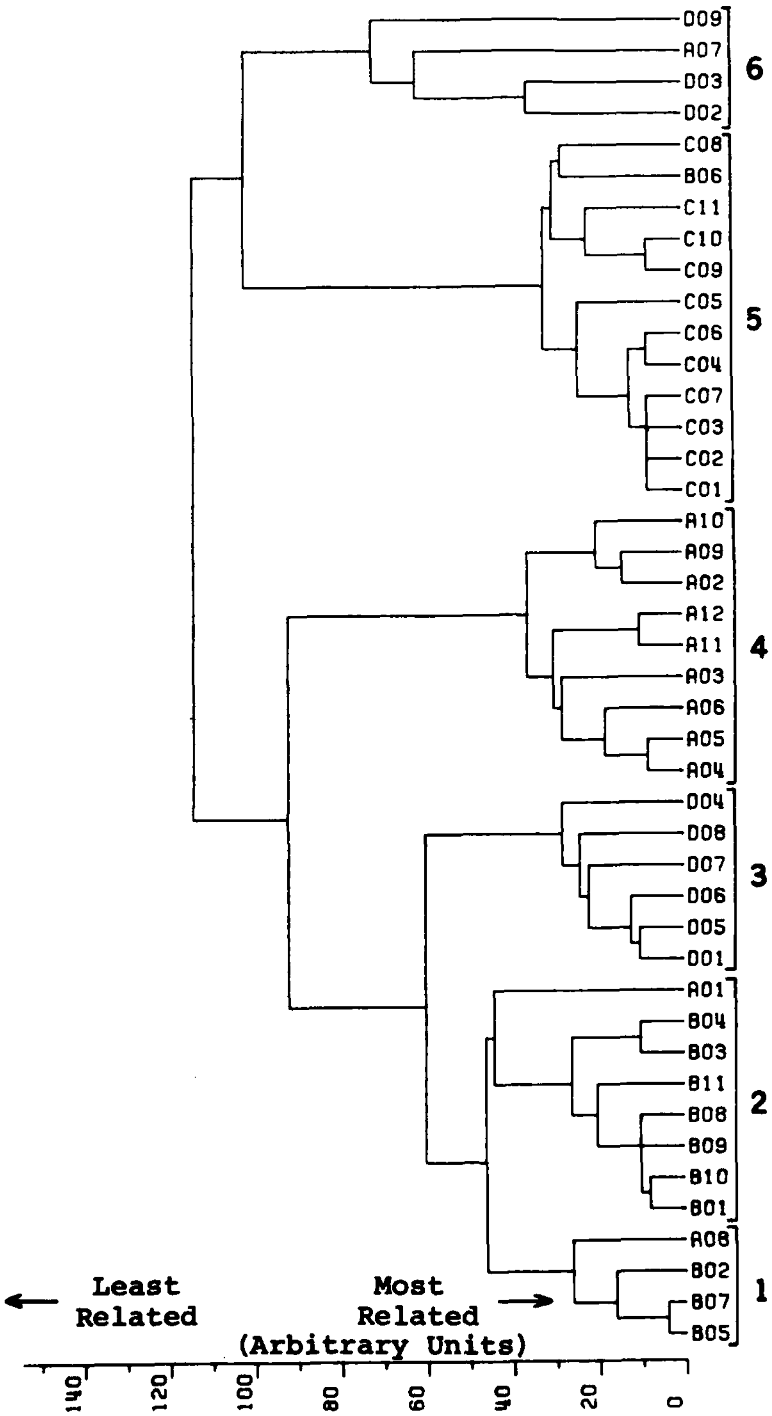


FIGURE 2.3

CIRCULATION PATTERNS IN LOS ANGELES–LONG BEACH HARBORS

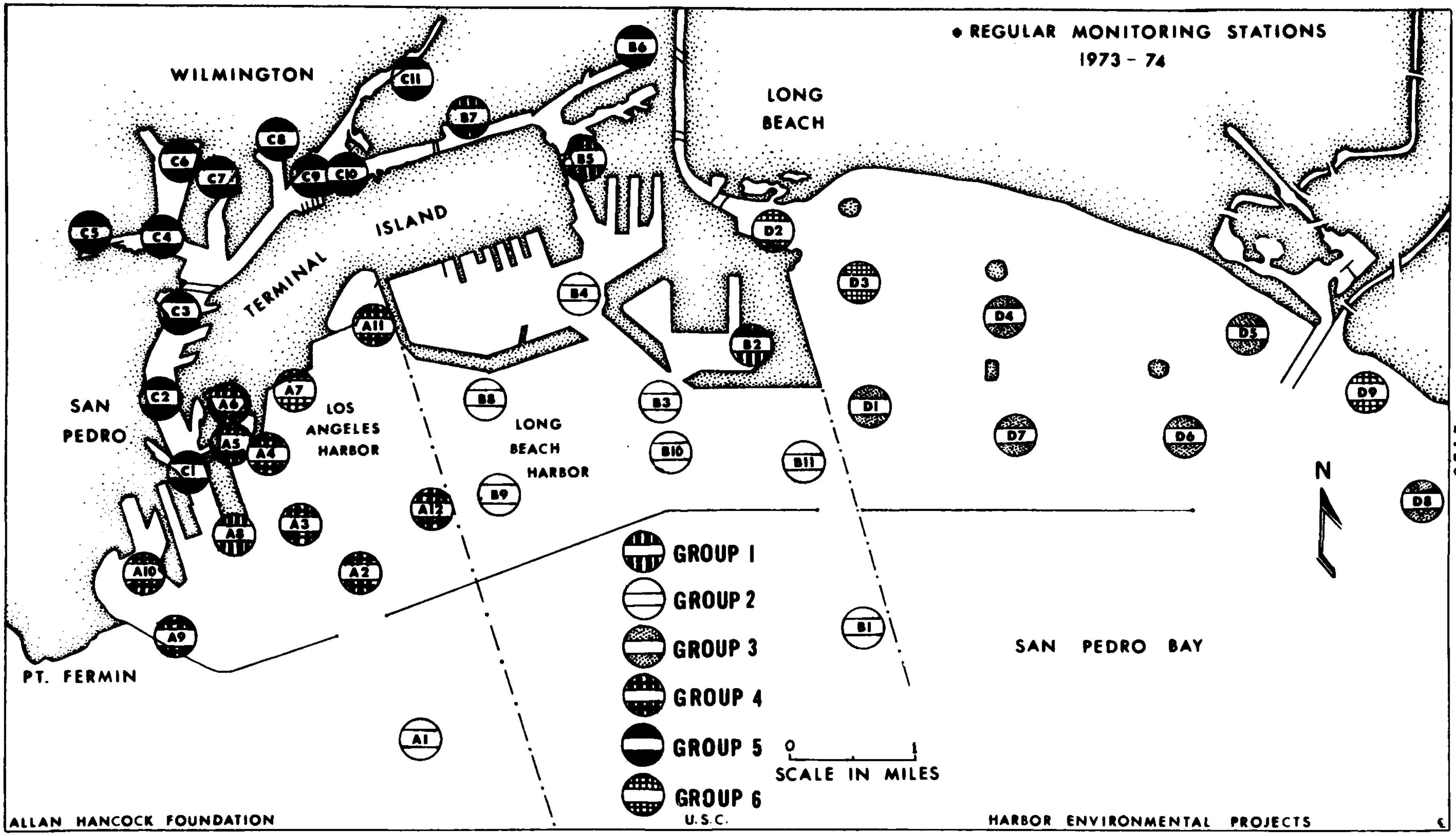
Source: Allan Hancock Foundation
Reference: Reish, 1959



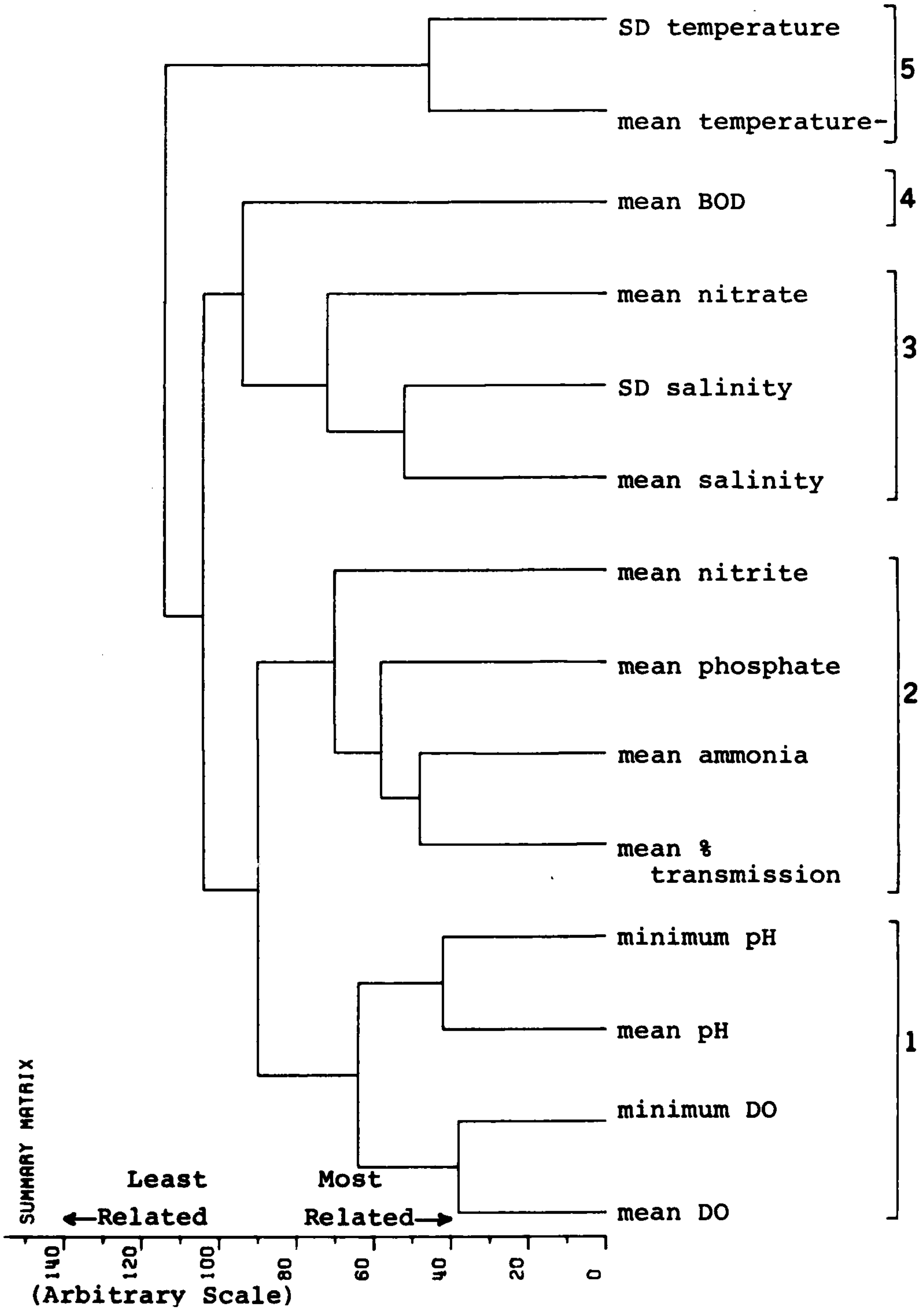
CLASSIFICATION OF STATIONS BASED ON THE SURFACE ABIOTIC PARAMETERS

Figure 2.4

The dendrogram is a computer-generated diagram which expresses the relationships between multiple parameters. The most closely related are grouped to the right, both horizontally and vertically, and relationships decrease toward the left.



STATION GROUPS CLASSIFIED ON THE BASIS OF ABIOTIC
SURFACE DATA
Figure 2.5



CLASSIFICATION OF THE SURFACE ABIOTIC VARIABLES
Figure 2.6

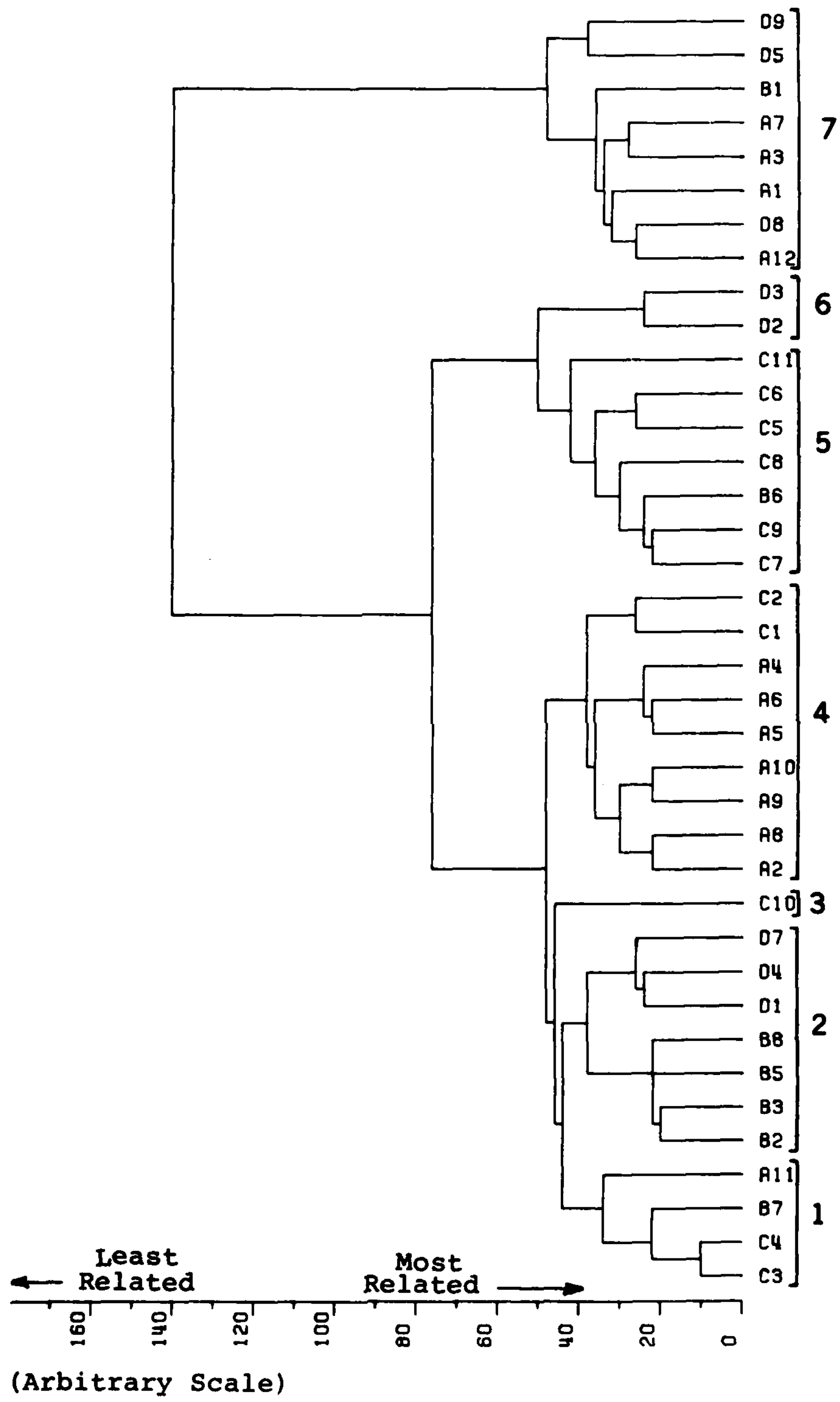
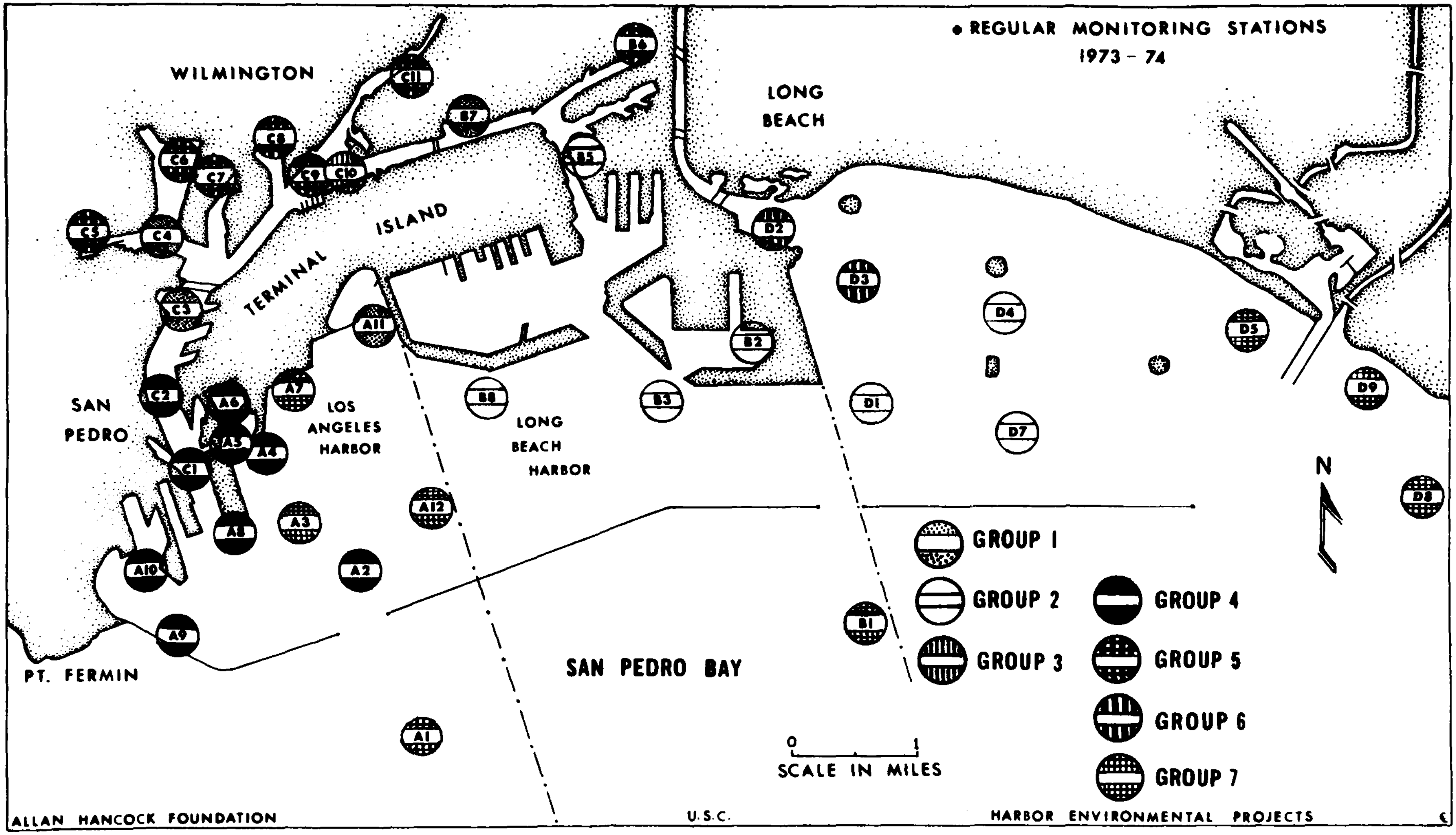


Figure 2.7
CLASSIFICATION OF STATIONS
BASED ON THE BENTHIC ABIOTIC DATA



STATION GROUPS CLASSIFIED ON THE BASIS OF ABIOTIC
BENTHIC DATA
Figure 2.8

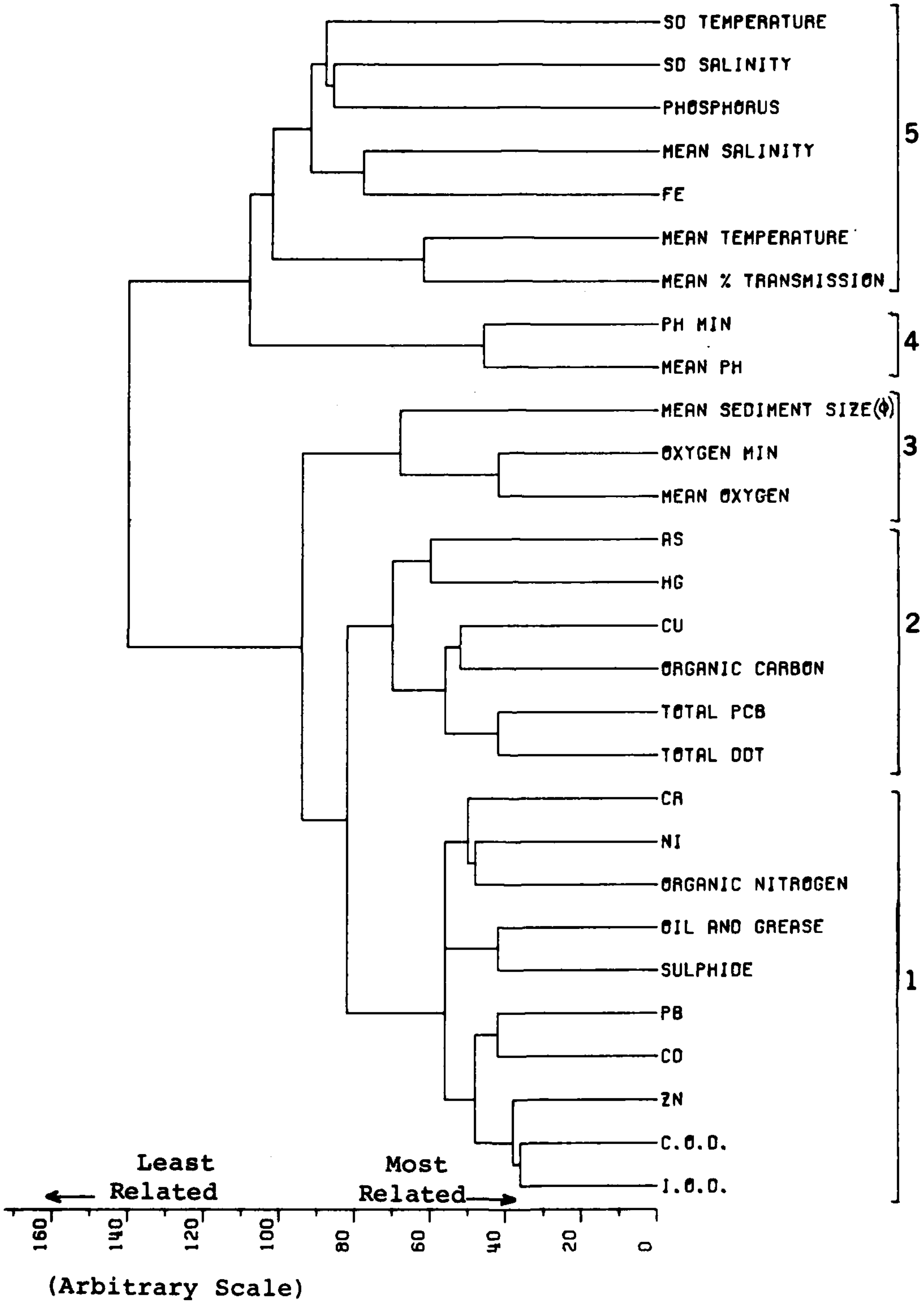
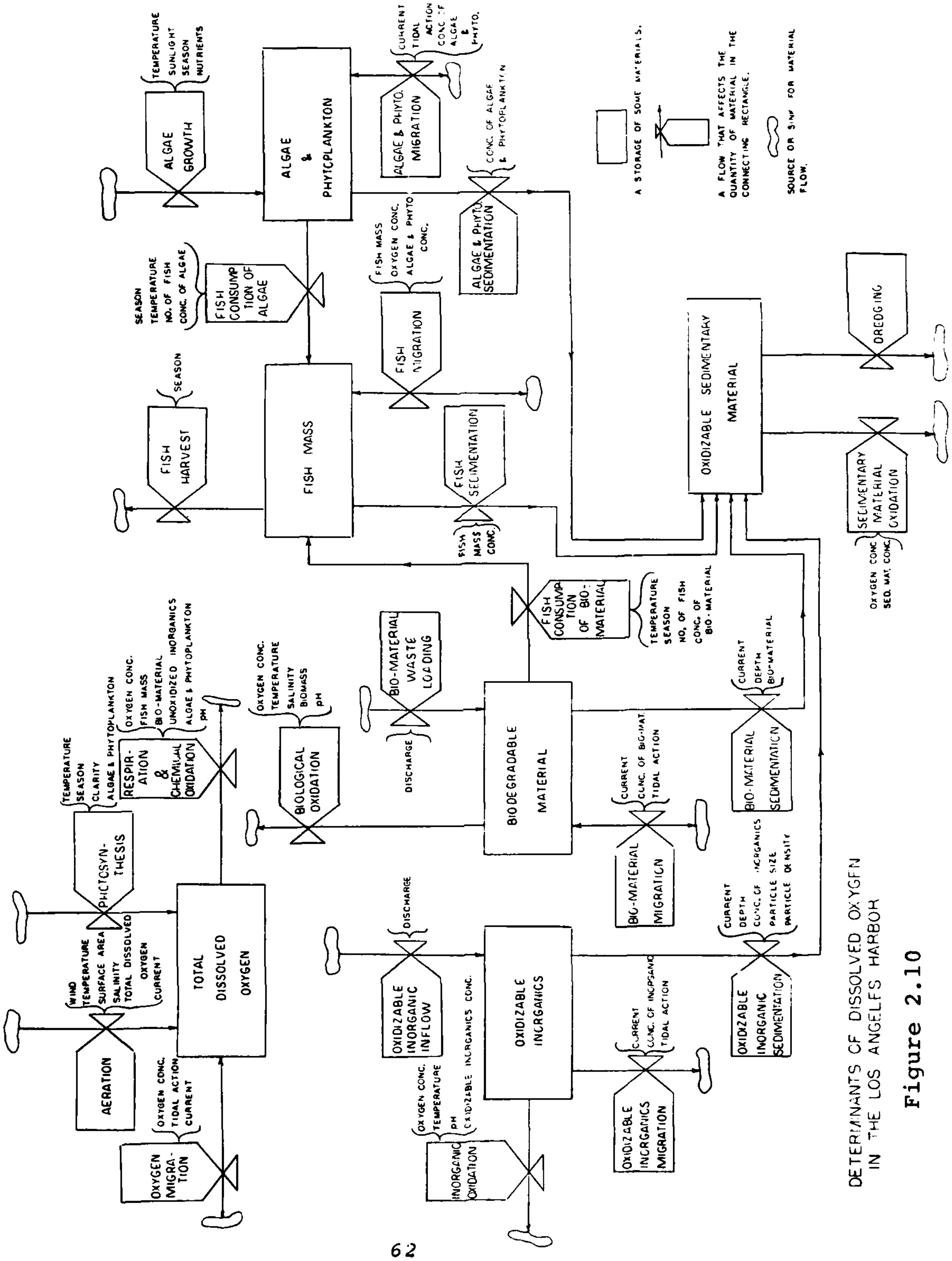


Figure 2.9
CLASSIFICATION OF THE BENTHIC ABIOTIC DATA



DETERMINANTS OF DISSOLVED OXYGEN IN THE LOS ANGELES HARBOR

Figure 2.10

STATION GROUPS

ABIOTIC DATA		I				II								III						IV									V												VI			
Mean DO				+		+	+	*	*	+	+	+		+	+	+	*	+	+	-	-	-			+		-		-	-	-	-	-	-	-	-	-	=		-	-	+	-	-
Minimum DO	I	+			-	+	*	*	+	+	+	+		+	+	+	*	+	-	-	-	-							-	-	-	-	-	-		-	-	-	=	-		+	=	
Mean pH		-	-		+	+	+	+	+				+	+	+	+	*	+	+										-	-	-	-	-	-	-	-	=	=	-	-	+	+		+
Minimum pH					+	+			+			+	+	+	+	*	*	*	+	-	-	-		-	-		+	+	-	-	-	-	-	-	-	-	=	=			+	+	-	+
% Transmiss.				-		+	+	+	+	+	+		+	+		+	+	+	+	=	-			-	-								-		-	+	+		=	+	=		=	-
Ammonia	II	+	+		+	=	=	-	=	-	-		-	-		=	-	+	-	+	+	+																+	+		*	+	*	+
Phosphate						=	-	-	-	-	-	-	=	-		-		-	-	+					-	-	-			+		+				+	+	+	+	+	+		*	*
Nitrite		+	+			-	-	-		-			=	-	-	-		-	-				*	-	-	=	-					+				+	+	+		+	*	*		+
Mean Salinity				+		+	+	+	+	+	+		+	+	+	+		+		-	-	-		-	-	-	-	-	+	+	+		+	+	+			=			=		=	
SD Salinity			-	-		-	-	-	-	-	-	-	-							+	+	+	+	+	*	*	*	*	-	-	-	-	-	-		-	-		-	-	+		+	
Nitrate	III				+	-	-	-	-	=	-		+	-	=	=	-	=	-					+	+	+	+	*							+	+	+	+	+			-	+	
BOD	IV				-	-					-	-		+		+	+	+	+			-					-	-					-	-							+	*	*	-
Mean Temp.	V				-	-	-	-	-	-	-		=			+	+			-	-		-		-	-	-	-			+		+	+	+									*
SD Temp.				-	=	-	-	-	-		-	-	=	+	+	+	-	+	+	-	-				-	-	-	-			+	+	+	+	*	+	+	+			+	+		*

TWO-WAY TABLE FROM THE CLASSIFICATION OF THE SURFACE ABIOTIC DATA
Table 2.1

No symbol indicates $\pm$ 0.5 standard deviations from mean,
+ or - indicates 0.5 to 1.5 standard deviations from mean
and * or = indicates greater than 1.5 standard deviations from mean.

ABIOTIC DATA	I	II	III	IV	V	VI	VII
IOD	- - -	+		- + + +	+ + + + + *	+ *	- - - = = =
COD	-	-		+ + + + +	+ + + - *	+ +	- - - - - = = -
Zn				+ + + +	+ + * + + *	+ +	- - = - = = =
Cd	-	-		+ + + - +	+ + + * *	+ +	- - - = - - - -
Pb I	- - -	-		+ + + +	+ + + *	* *	- - = - = -
Sulfide	- - -	+		- -	+ + + * + + *	* *	- - - = - - -
Oil & Grease	- -	+ + +		- +	* + + + + + *	+ +	= - - = - - -
Org. N	- -	+ +		- - +	+ + * + +	+ +	- - = - - - = -
Ni	- - - -	+ +	-	+ + + -	+ * * *	+ +	- - - - - - - -
Cr	-			+ -	+ + * * + + *		- - = = - - =
Total DDT	- -	-		* + + + + +	+ + + *	+	- - - - = =
Total PCB	-	- - - - -		+ + + + + +	+ + + + + *	+ +	- - = = =
Org. C II	- - -	- - - - -		+ + * + + + + +	+ + *	+	- - - - = =
Cu		- -		+ + * + * +	+ * + + +		- = - = - + = =
Hg	+ -	- - -	+	- + + + + + +	+ + * * + +	=	- - - = =
As	-	+ - - +		+ - - +	+ * * * - *	+	- - - - - = =
Mean Oxygen	+	+ -		+ = = + +	- - - = - -	= =	+ + + + * +
Oxygen Min.	+	+ - -		= = + +	+ - =	- =	+ - + * *
Mean Sed. Size (Ø) III	- -	+ + - - + +	+	- + + + =	+ + + + + +	+ +	- = - + = - =
Mean pH	+ +	+ + + + - =		- - = - - + +	+ + +	= -	- - - + + +
pH Min. IV	-	+ * * + = - -	-	- - - - - - - +	+ + * * +	= -	- - - +
Mean % Trans.	- - - -	+ - - +	-	* + + + =	- - - - -		+ * + * + =
Mean Temp.	+ + + +	- - = - -	-	- - + +	+ + + * + +	-	- - = + = +
Fe	- - -	* * +		* * + -	+ +	+	- - = = = - -
Mean Sal. V	+ + *	+ + +		- - - -	- + - + -	+ +	+ = + - - -
Phosphorus	- - -	- - *	+	- = + + * +	+ -	- -	- = - - *
SD Salinity	*	- - - + =		- + + + + + +	= + - -	= +	- + + + -
SD Temp.	- - + +	- - - -	*	+ + - -	-	-	- + +

TWO-WAY TABLE FROM THE CLASSIFICATION
OF THE BENTHIC ABIOTIC DATA
Table 2.2

Chapter 3

PHYTOPLANKTON PRODUCTIVITY

PHYTOPLANKTON PRODUCTIVITY IN THE LOS ANGELES-LONG BEACH HARBOR AREA

INTRODUCTION

Primary productivity, the ability of photosynthetic organisms to convert non-living nutrients into biological material, is an index to the fertility of the waters being tested. It is a measurement of the ability of the waters to support the initial production of the nutritional substrate on which the rest of the trophic structure feeds, and, in conjunction with determinations of the size of the photosynthetic population, it can be used to assess the metabolic health of the population.

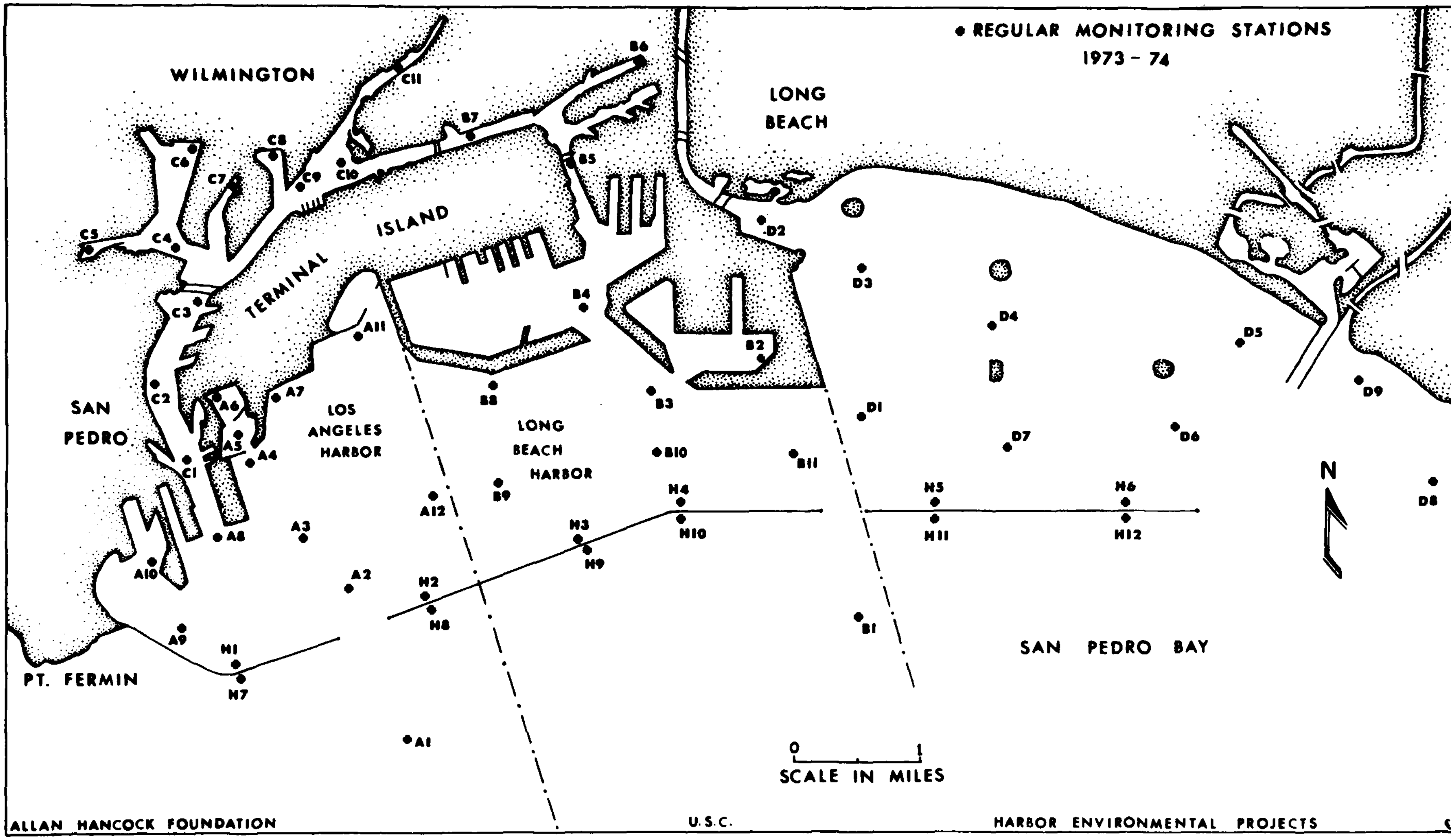
The measurement of primary productivity differs from most biological methods used in the present study, because it represents a rate of a biological process, photosynthesis, rather than a measurement of a quantity of biotic material present.

The process of photosynthesis is sensitive to environmental changes and the presence and concentration of substances such as fertilizer salts and toxins. Consequently, this measurement is useful in assessing the impact of environmental quality on the biota and has been used for this purpose elsewhere (Tibby, et al., 1965).

METHODS AND MATERIALS

Data on productivity of the Los Angeles-Long Beach Harbor were obtained by collecting samples at the Harbor Environmental Project stations shown in Figure 3.1, at monthly intervals. Three types of information were obtained: productivity, which is a measurement of the ability of organisms to convert non-living nutrients into living material photosynthetically; standing crop, which is reported here as chlorophyll *a* and gives information on the size of the population that is involved in the productivity being measured; and assimilation ratios, which give an index to the efficiency with which the standing crop is able to produce.

Primary productivity determinations were made using a modification of the isotopic carbon method, first described by Steeman Nielsen (1952). Duplicate clear and black plastic-coated, 125 ml, glass-stoppered bottles were filled with water from the sampling station. To each was added a known quantity of radioactive carbon as carbonate or bicarbonate. The bottles were then incubated at ambient seawater temperature under controlled illumination for about three hours. The contents of the bottles were then filtered through Millipore AA filters, and the cells containing the assimilated radioactive carbon were



PRODUCTIVITY STATIONS IN THE LOS ANGELES-LONG BEACH HARBORS

Figure 3.1

retained on the filters. The proportion of assimilated carbon was determined. The data are reported as milligrams of carbon fixed per hour of incubation per cubic meter of water sampled.

Standing crop determinations were made by measuring the quantity of chlorophyll *a* present per liter of water sampled. A known volume of water was filtered through Millipore HA filters and the pigments were extracted into 90% acetone from the cells retained on the filter. The pigments in the extract were then determined spectrophotometrically. The equations of Strickland and Parsons (1968) were used to calculate pigment values, expressed as milligrams per liter of water sampled.

Assimilation ratios were not directly measured but were calculated by dividing the values determined for productivity by the values determined for chlorophyll *a* concentrations.

The productivity values reflect the ability of the population present, regardless of size, to produce organic material under the conditions prevalent in the waters sampled. This reflects the fertility of the waters being sampled and gives an index to the production and availability of food to organisms which require an organic substrate but cannot synthesize their own.

The chlorophyll *a* values are used as a measure of the standing crop of phytoplankton population present at the time and place of sampling. This does not give an enumeration of the numbers and species present, but does give a more easily and rapidly obtainable value. The quantity of pigment available to catalyze the conversion of non-living carbon sources into living material is not constant for different species or different cells, but is nevertheless an acceptable estimation of standing crop.

Assimilation ratio is defined as the capacity of a unit of the standing crop to assimilate non-living nutrient and convert it to living material. Determinants of this value include the physiological state of the organisms present, the availability of nutrients, and the presence of inhibiting or toxic substances. The values, as determined, do not identify the controlling factor but are a statement of the summation of all factors involved. As such, it can indicate a population stressed by limiting or inhibiting conditions or a population in the process of rapid growth.

RESULTS

Variations in Space

San Pedro Bay is subject to sporadic outbreaks of intense phytoplankton blooms, including red tides. These blooms vary in intensity and areal extent and usually, but not invariably, occur during the warm weather months.

The major areas affected include the area near the mouth of the Los Angeles River, the outer harbor south and east of Fish Harbor and inner Long Beach Harbor, particularly the area near B6. As an empirical index, it was assumed that productivity values of over 50 milligrams of carbon fixed per cubic meter of water sampled, per hour of incubation, represented a phytoplankton bloom. On this basis, only stations A1 and B1, at the sea buoys off the entrance to both harbors, and stations B10 and B11, in outer Long Beach Harbor, have not shown evidence of such a bloom during the 1973 and 1974 study period. Stations B3 (94.2 mg C/hr/m^3), C10 (75.0 mg C/hr/m^3) and station D9 (52.1 mg C/hr/m^3) showed only one incident each and these occurred when red tide covered the entire general area near these stations.

Values for productivity, chlorophyll *a*, and assimilation ratio based on chlorophyll *a* at each station were averaged for the years 1973 and 1974. These data are presented in Figures 3.2-3.7 for the two years. Oguri (1974) previously presented data from the A stations during 1971-1973.

Productivity and chlorophyll *a* tend to be lower in the western part of the harbor and in the outer harbor areas. The stations to the east of Pier J, Long Beach, and the stations of inner Long Beach Harbor are the highest in both of these measurements. Lower values are associated with the stations at the sea buoys of both harbors, the outer Los Angeles and Long Beach Harbors and inner Los Angeles Harbor.

In the area to the east of Pier J, in Long Beach, there is a pattern of high productivity and high chlorophyll *a* at the mouth of the Los Angeles River, Stations D2 and D3, which is reduced in value with distance from the river mouth. A reverse pattern is seen in the assimilation values. This pattern holds true for both 1973 and 1974.

A similar pattern, although not as clear, is also apparent in the Long Beach Harbor stations, with high productivity

and chlorophyll *a* at the inner harbor station B6. Assimilation values, however, do not show a consistent trend.

The stations in the outer harbors and in inner Los Angeles Harbor, as a whole show lower values for productivity and chlorophyll *a* than the inner Long Beach Harbor or the area to the east of Pier J, Long Beach. Although no consistent trends are evident in the data from these stations, certain stations lying close to one another show enough similarity to permit consideration of them as groups.

Grouping the stations was accomplished through consideration of similarities in the patterns existing in productivity, chlorophyll *a* and assimilation ratio. The data for the two years, each year considered separately, were transformed, and if necessary, normalized and standardized. They were then ranked and grouped, using a normal Euclidean distance program.

Based on this classification, those stations lying in close proximity to one another, both physically and in the classification, were considered as a group that probably was primarily controlled by the same environmental factors.

In the inner Los Angeles Harbor, stations C8, C9, C10 and C11 form one such group. These stations show low chlorophyll *a* and low to moderate productivity and assimilation ratio. With the exception of C8, these stations are located in the direct path of any flow from Dominguez Slough and may be influenced by this. C8 may also be affected, since tidal flushing could carry the same water into Slip 5, the area of that station. It is surprising to note the lack of similarity in C10, the easternmost inner Los Angeles Harbor station, and B7, the westernmost inner Long Beach Harbor station. The sampling of these stations was generally one week apart and the distance separating them was about one mile. Several possible isolating mechanisms may exist between the two stations, including the narrowing of the channel at the Henry Ford Bridge, and the relative insignificance of currents in the channel as compared to the volume and influence of the flow from Dominguez Slough. This is the area where the two tidal inputs from the main channels meet. It is possible that the area between C10 and B7 represents a damped area of flushing. Preliminary data from the Corps of Engineers Waterways Experiment Station model study of the harbor at Vicksburg, Mississippi suggest that tidal currents in the area are very weak. The model does not simulate flow from the Dominguez Slough.

Stations C1, C2 and C3 in the Los Angeles main channel

also show a similarity to one another, which suggests that they are related with regard to productivity, chlorophyll *a*, and assimilation ratios. Since currents in this channel appear to be of sufficient magnitude to keep the water well mixed, this is not surprising.

Stations C4, C5 and C6 in West Basin, and station C7 in Slip 1 did not cluster into any group. Each of these stations is either isolated physically or shows a different pattern in data distribution. Station C6, although similar in data to C1, C2 and C3, is isolated from them and is in an area of warm water effluent. C5 and C7 show similar data patterns, and are in the ends of slips where circulation is poor, but are isolated from one another in different areas. C4 does not fit into any of the adjacent groups.

Stations A1 and B1, outside the harbor, form a group that is felt to be representative of the waters beyond the breakwater. Productivity and chlorophyll *a* values are lower at these stations and intense red tide blooms seldom occur.

Station A2 and, to a lesser extent, station A3, are influenced by water outside the harbor as well as water inside the harbor.

In the outer harbor, stations A8, A9 and A10 form another group. Stations A9 and A10 are situated in a cul-de-sac which isolates them from other stations. Station A8, at the entrance to the main channel, lies in the path of the current gyre that serves as the major flushing mechanism for A9 and A10. This counter-clockwise gyre can be seen in the results of a drogue study (Soule and Oguri, 1972) and in the preliminary data of the Vicksburg model study.

Stations A4, A5 and A6, located in or at the entrance to Fish Harbor, and possibly station A3, form another group whose affinities are probably related to the relatively poor flushing of Fish Harbor and the influence of the outfalls located at station A7.

Stations A11, A12, B9 and B10 in the outer harbor do not show consistent agreement in the data and are probably most influenced by the outfalls at A7. These stations, with the exception of A11, are also influenced by the major current gyre that dominates water circulation in the outer harbor.

In Long Beach Harbor, stations B4 and B8 show a strong similarity for both years in all these values. Inspection of the preliminary data from the Vicksburg model study shows that on a rising tide much of the water entering the Long Beach

main channel comes from the major gyre in the outer harbor. This water sweeps past B8, into the channel and past B4. On an outgoing tide the process is reversed. The only earlier diagram (Reish, 1959) of current patterns prior to construction of Pier J indicated a stronger flow toward the main channel and outer harbor from the Queens Gate entry. This is now partly deflected toward D1.

In inner Long Beach Harbor, station B6 has the highest primary productivity and chlorophyll *a* values. The poor circulation in the area coupled with presumed enrichment from the effluents in the area are contributing factors in maintaining the levels of productivity there. It is felt that stations B5 and B7 reflect the influence of this station.

The other B stations show no consistent similarity to groups in their immediate vicinity. Station B2 is isolated within Pier J basin, and station B3, near the entry to this basin, shows an affinity for both B2 and the stations in the major current gyre. Station B11 appears to be transitional between the D series of stations to the east and station B1 outside Queens Gate.

The D stations as a whole are the most productive and have the highest chlorophyll *a* concentrations. Stations D1, D8 and D9 are allied in being located in areas of good circulation. The Los Angeles River apparently exerts a strong influence on station D2, at its mouth, and stations D5, D6 and D7 form another group based on similarities in patterns of productivity. They are probably influenced by the nearby oil islands.

Variations in Time

The general pattern of seasonal changes in the harbors is obscured to a degree by the occurrence of phytoplankton blooms such as the red tides mentioned above. These blooms occur most intensely and most predictably, but not exclusively, in the late summer and early fall, with July, August and September being months principally affected. The magnitude of these blooms can extend to over 400 milligrams of carbon fixed, per hour of incubation, per cubic meter of water, by a population containing up to 35 milligrams of chlorophyll *a* per cubic meter.

The late fall and early winter months of October, November and December generally show a sharp drop from the levels of July through September, and an irregular drop in levels of productivity and chlorophyll *a*. The winter lows occur in January and February. Low values during this period are often

below 1 milligram of carbon fixed per hour of incubation, per cubic meter of water sampled, and .5 milligrams of chlorophyll *a* per cubic meter of water sampled.

Sometimes during March through May there is a moderate bloom, principally of diatoms at most sites within the harbor. This bloom, although not usually as intense as the late summer-early fall bloom, can exceed productivity as high as 100 milligrams of carbon fixed, per hour of incubation, per cubic meter.

Following a brief hiatus in the months of May or June there is usually a secondary bloom, primarily of dinoflagellates.

Interrelationships

Interrelationships are of interest in determining the role of phytoplankton in harbor ecology.

Correlations between the three types of data: productivity, chlorophyll *a*, and assimilation ratio, at all stations for all times occupied were calculated. The stations at which significant correlations ($p \leq 0.05$) were found between chlorophyll *a* and primary productivity (Figure 3.8) include all of the inner harbor, the western side of outer Los Angeles Harbor including station A1 at the sea buoy, the Fish Harbor stations, the northern part of outer Long Beach Harbor and all but two stations, D4 and D9, to the east of Long Beach Harbor.

This type of correlation suggests that change noted in the productivity of these areas is usually associated with change in the photosynthetic population. The regulation of production in this case could be due to limiting factors among the physiological needs of the phytoplankton.

Significant correlations between chlorophyll *a* and assimilation ratio are shown in Figure 3.9. With the exception of station A4 at the entrance to Fish Harbor, all of the significant correlation coefficients are negative. This indicates that the phytoplankton in these areas are probably under stress for a significant proportion of the times sampled and, although viable, are incapable of maintaining normal assimilation rates.

Significant correlation coefficients between productivity and assimilation ratio were found at stations shown in Figure 3.10. The major areas showing this correlation are in the outer harbor, the area east of Long Beach Harbor and the northern part of inner Long Beach Harbor. This type of correlation suggests that a given population of photosynthetic organisms is either stimulated, or has some inhibition removed, permitting increased productivity per unit of population. The three largest of these areas correspond roughly to the areas where dinoflagellate blooms (red tides) have been seen to occur most frequently.

Only one of the 43 stations routinely sampled during this study, All, had no significant correlation coefficients.

The occurrence of two or more different types of significant correlations at some stations suggests that the operational control of the phytoplankton population and its processes is regulated by more than one factor which may be different at different times. Synergistic effects probably are also involved in the regulatory mechanisms.

White Tides, Red Tides and Green Tides

Although the trend may not be statistically significant, the phytoplankton productivity peaks appear to be inversely related to total coliform count peaks, and to some extent, to total plate count peaks.

It has been hypothesized that bacterial "blooms" may precede phytoplankton blooms, releasing growth factors or hormones to the water as the bacterial bloom dies off. Following the phytoplankton bloom, die-off occurs which undoubtedly stimulates bacterial increases during breakdown of dead phytoplankters. However, the limited techniques for identifying the marine microorganisms possibly involved in this cycling preclude verifying the hypothesis at this time.

Certainly there are times when a milky white or turquoise colored suspensate can be seen in patches of water, especially when viewed from the helicopter. Sampling has proved inconclusive; at times no bacteria could be cultured from the patches, and at other times anaerobes were taken in surface water samples. It is possible that stirring of anaerobic bottom muds may be involved. The white patches have been seen at A4, where fishing vessels and small craft enter the shallow Fish Harbor area within Fish Harbor at A5 and A6 and at the outfalls at A7. Aerial observation and photos show this white water can extend from the area around Fish Harbor in any direction, depending on wind and current.

This white water phenomenon differs from the wastes discharged from the canneries in being distributed more uniformly with depth and more evenly horizontally. The cannery wastes tend to float on or near the surface and to coagulate or flocculate into aggregates that are less evenly distributed.

The most intense white water occurrences have been noted in the fall, coinciding in time with the season when hot dry winds, locally referred to as Santa Ana winds, are most likely to blow. Fall is also the season when water quality throughout the harbor sometimes drops below levels considered acceptable by State and Regional Water Quality Control standards, as shown

by low dissolved oxygen, and red tide may be expected in the harbor and also along the coastline.

The red tides that occur in the harbor sporadically have generally been of two types. Those that occur in late spring or early summer are usually less dense are are more localized and not associated with the white tide phenomenon discussed above. A dominant organisms in these blooms is often *Procentrum micans*, a dinoflagellate that has been reported in California red tides but has never been associated with mortality of marine organisms.

Red tides occurring in late summer or early fall are dominated by *Gonyaulax polyedra*, an armored dinoflagellate which has been associated with fish kills. These blooms at times coincide closely in time and space with the white water discussed above (Oguri, et al.,1975) and may, in fact, obtain growth factors from the white tide, even though its composition is open to question. Red tide is found most frequently in three areas of the harbor: the outer Los Angeles-Long Beach Harbors, Channel 2 of the Port of Long Beach, and in the area to the east of Pier J, particularly near the mouth of the Los Angeles River.

The red tide occurrences in the harbor, their relationship to bacterial activity and white tides and their trophic role in the environment are questions beyond the scope of the present study. Further research under other funding is planned on these and other related problems.

Green tides have been seen in the harbor, occurring both as a general phenomenon and as localized blooms.

In spring there is a general bloom, primarily of diatoms, that gives a greenish cast to the harbor waters. This occurs generally in coastal waters as well. Almost the entire harbor shows some signs of this blooms, although it may be less dense in some areas. It is considered a normal cyclic occurrence.

Sporadic outbreaks of green water, more localized and sometimes more intense, have also been noted. Three of these, one occurring in Slip 1 of Los Angeles Harbor in August and another in outer Los Angeles Harbor in June, 1973, and the third in the outer Los Angeles Harbor in August of 1973, were examined closely. The dominant organisms was of the genus *Eutreptia*, a euglenoid flagellate. This genus has been reported widely from estuarine and harbor environments and is noted to be tolerant of polluted environments.

Collections of phytoplankton were made twice weekly during 1976 at four stations: one outside Angels Gate (A1), one near inner Cabrillo Beach (A9), another midway between Reservation Point and the Navy Mole, and the last near the mouth of the Los Angeles River (D3). Small blooms have been sampled and the organisms cultured in the laboratory. Some 25 species have been indentified from these blooms, but *Gonyaulax* has not been dominant in any 1976 bloom.

DISCUSSION

The effluents discharged into San Pedro Bay and their distribution by the currents and stirring in the area are major factors in establishing the overall patterns of phytoplankton abundance. On the basis of similarities in the chlorophyll *a* concentrations and productivity data, a rough grouping can be made of the stations. Computer plots of annual mean values, as seen in Figures 3.2 through 3.7 display the resultant patterns.

The restricted flushing rate of San Pedro Bay, coupled with the nutrient inputs, results in the high levels of population and primary productivity and the frequent occurrence of blooms such as red tides. These occur throughout most of the harbor but are most intense in Channel 2 of Long Beach Harbor, outer Los Angeles Harbor and the area of the east of Pier J, Long Beach Harbor.

The seasonal variations in chlorophyll *a* concentration and productivity within the harbor coincide with the variations outside the harbor, but show a far greater magnitude.

Significant correlations found at different stations between chlorophyll *a*, primary productivity, and assimilation ratio are shown by the large dots in Figures 3.8-3.10. The correlations suggest that the phytoplankton population and its processes are regulated by presence or absence of limiting biotic or abiotic factors.

IMPACT ON PHYTOPLANKTON PRODUCTIVITY OF PROPOSED CONSTRUCTION

The proposed alterations to the harbor will result in reduced water area, increased channel depths and the creation of dead-end slips, those with one end closed. The resultant changes in phytoplankton productivity and pigment concentrations will vary considerably.

Reduced water area and increased channel depths tend to reduce productivity and chlorophyll concentrations by reducing the total input of light available for photosynthesis. If greater current velocities prevail in the inner harbor, the improved flushing will further promote a reduction in these parameters.

The dead-end slips presently in existence represent problem areas in the harbor. They are subject to periodic blooms of different organisms whose occurrence is probably triggered by the release of some material discharged in the immediate vicinity. The poor flushing characteristics of those slips prevents the material from dissipating.

Two major factors influencing the projection of impacts in the harbor which can't be addressed with the information at hand are the fate of waste water discharges presently existing in the harbor and the flushing rate expected in the various parts of the harbor following construction.

Dredging may affect the phytoplankton temporarily; by increasing turbidity which would limit photosynthesis, by creating heavy oxygen demand, by release of toxicants or biostimulants. This would in turn affect the zooplankton and other phytoplankton feeders.

Location of any landfill associated with the interim or LNG terminal is crucial; a solid barrier extending south from thenavy mole would disrupt the major circulation gyre, decreasing the assimilation capacity of the harbor. This would result in degradation of water quality and probably increase severe bloom conditions.

If the master plans for both ports were completed, bacteria and phytoplankton would probably dominate the biota, as is typical of eutrophic conditions in freshwater lakes.

LITERATURE CITED

Neilsen, E. Steeman. 1952. The use of radioactive carbon (^{14}C) for measuring organic production in the sea. Rapp. Cons. Explor. Mer. 144:92-95.

Oguri, M. 1974. Primary productivity in Outer Los Angeles Harbor. In Marine Studies of San Pedro Bay, California. Part 4. Allan Hancock Foundation and USC Sea Grant Program. University of Southern California. p. 79-88.

Oguri, M., D.Soule, D.M.Juge, B.C.Abbott. 1975. Red tides in the Los Angeles-Long Beach Harbors. In Marine Studies of San Pedro Bay, Califoria. Part 8. Allan Hancock Foundation and USC Sea Grant Program. University of Southern California. p. 109-119.

Reish, D.J. 1959. An ecological study of pollution in Los Angeles-Long Beach Harbors, California. Allan Hancock Foundation, University of Southern California. Occas. Paper 22:1-119.

Soule, D.F. and M.Oguri. 1972. Circulation patterns in Los Angeles-Long Beach Harbors. Drogue study atlas and data report. Marine Studies of San Pedro Bay, California. Part 1. Allan Hancock Foundation and USC Sea Grant Program, University of So. California. p. 1-113.

Strickland, J.D.H. and T.R.Parsons. 1968. A practical handbook of seawater analysis. Fish. Res. Bd. Canada Bull. 167. 311 pp.

Tibby, R.B., J.E. Foxworthy, M. Oguri, and R.C. Fay. 1965. The diffusion of wastes in open coastal waters and their effects on primary biological productivity. Comm. Expl. Sci. Mer. Medit. Symposium de Monaco. 95-114.

Mean Productivity, 1973

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	9.47	15.66	21.88	28.99	34.30	40.51	46.72	52.92	59.13	65.34
MAXIMUM	15.68	21.88	28.09	34.30	40.51	46.72	52.92	59.13	65.34	71.55

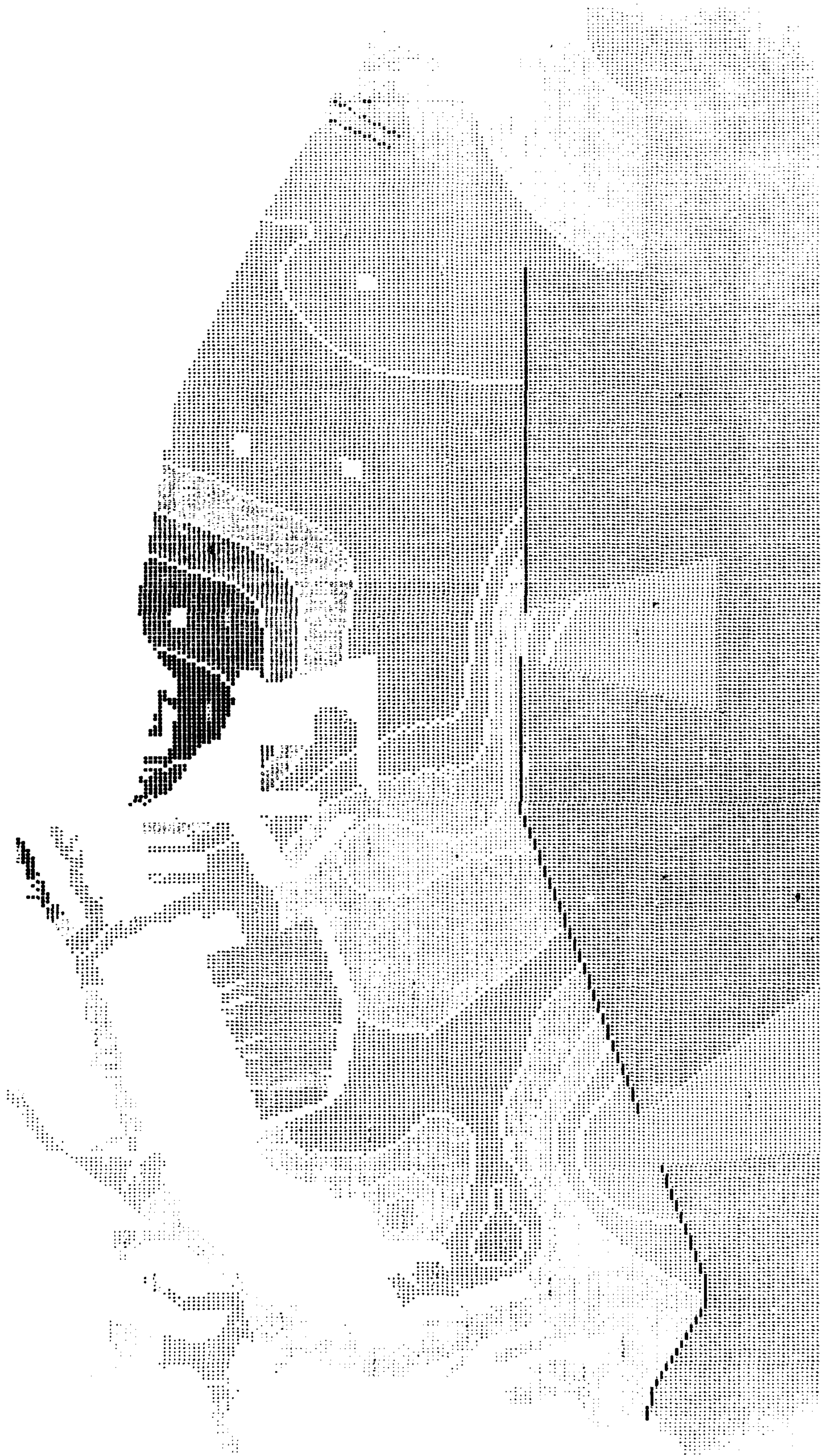
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	....1....	''''2''''	----3----	====4====	++++5++++	XXXX6XXXX	0000700000	8888888888	9999999999	##########
FREQ.	3	6	5	6	11	6	1	0	1	2

```
      1   I..1..I  I''2''I  I--3--I  I==4==I  I++5++I  IXX6XXI  I0070OI        IXX9XXI  I##*##I
      2   I..1..I  I''2''I  I--3--I  I==4==I  I++5++I  IXX6XXI                          I##*##I
      3   I..1..I  I''2''I  I--3--I  I==4==I  I++5++I  IXX6XXI
      4            I''2''I  I--3--I  I==4==I  I++5++I  IXX6XXI
      5            I''2''I  I--3--I  I==4==I  I++5++I  IXX6XXI
      6            I''2''I           I==4==I  I++5++I  IXX6XXI
      7                                       I++5++I
      8                                       I++5++I
      9                                       I++5++I
     10                                       I++5++I
     11                                       I++5++I
```



Mean Productivity — 1973
Figure 3.2

Mean Productivity, 1974

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

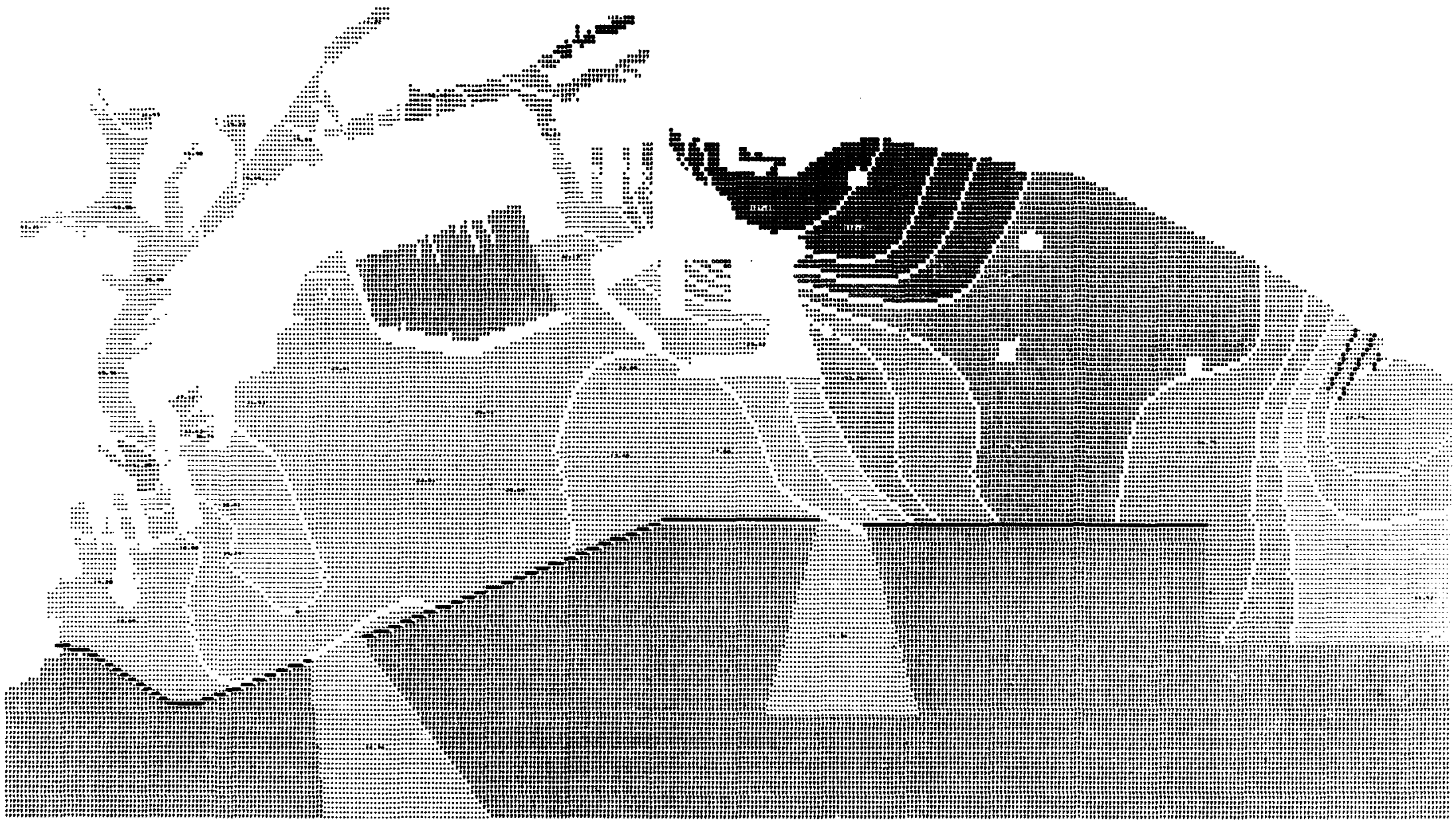
MINIMUM	11.22	22.80	34.38	45.95	57.53	69.11	80.69	92.27	103.85	115.43
MAXIMUM	22.80	34.38	45.95	57.53	69.11	80.69	92.27	103.85	115.43	127.01

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	....1....	''''2''''	----3----	====4====	++++5++++	XXXX6XXXX	000070000	888888888	9	10
FREQ.	13	10	10	2	2	3	0	0	2	1



Mean Productivity — 1974

Figure 3.3

Mean Chlorophyll *a*, 1973

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

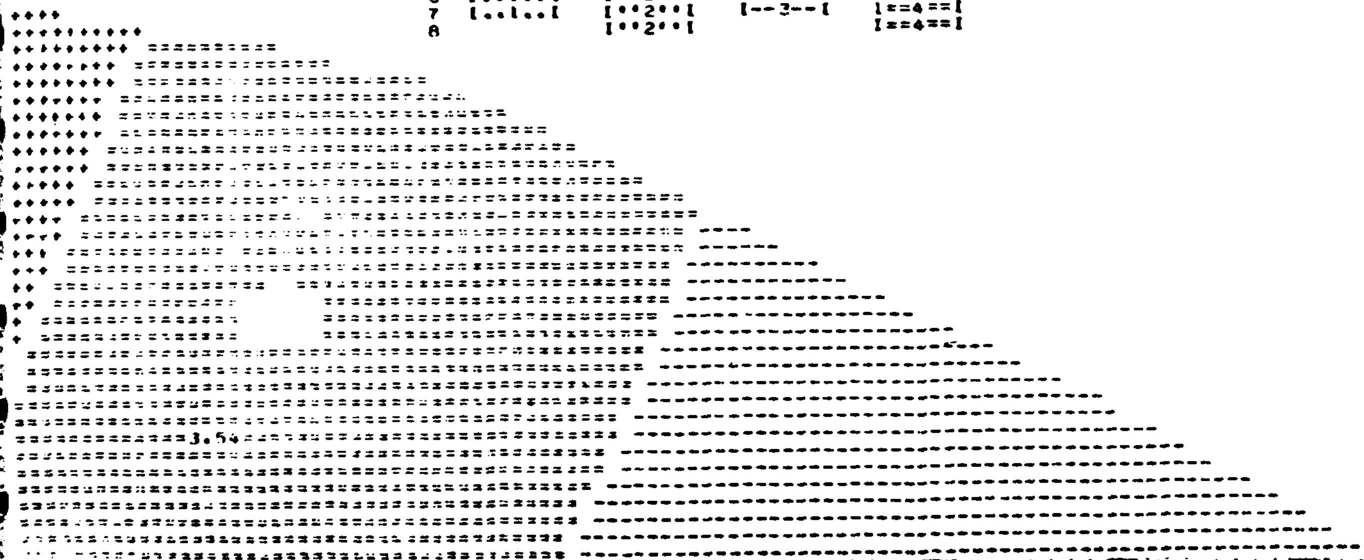
MINIMUM	1.17	1.89	2.60	3.31	4.03	4.74	5.45	6.17	6.88	7.59
MAXIMUM	1.89	2.60	3.31	4.03	4.74	5.45	6.17	6.88	7.59	8.30

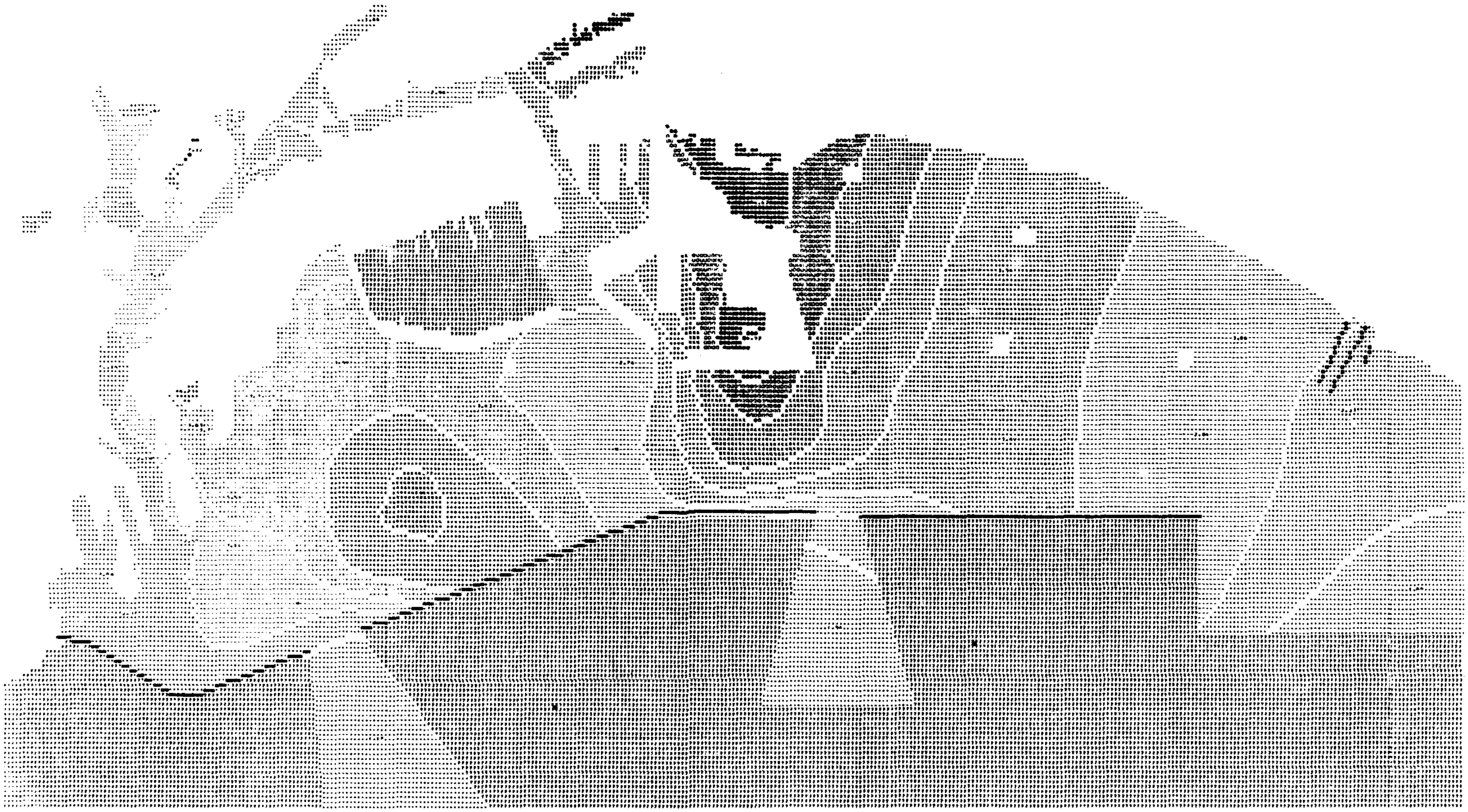
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

```
LEVEL         1          2          3          4          5          6          7          8          9          10
          ==========================================================================================================
          .........  .........  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  AAAAAAAAA  KKKKKKKKK  ■■■■■■■■■
          .........  .........  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  AAAAAAAAA  KKKKKKKKK  ■■■■■■■■■
SYMBOLS   ....1....  ....2....  ----3----  ====4====  ++++5++++  XXXX6XXXX  OOOO7OOOO  AAAA8AAAA  KKKK9KKKK  ■■■■■■■■■
          .........  .........  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  AAAAAAAAA  KKKKKKKKK  ■■■■■■■■■
          .........  .........  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  AAAAAAAAA  KKKKKKKKK  ■■■■■■■■■
          ==========================================================================================================
FREQ.         7          8          7          8          4          2          0          1          2          1
     1    I..1..I    I..2..I    I--3--I    I==4==I    I++5++I    IXX6XXI               IAAAAAI    IKK9KKI    I■■■■■I
     2    I..1..I    I..2..I    I--3--I    I==4==I    I++5++I    IXX6XXI                          IKK9KKI
     3    I..1..I    I..2..I    I--3--I    I==4==I    I++5++I
     4    I..1..I    I..2..I    I--3--I    I==4==I    I++5++I
     5    I..1..I    I..2..I    I--3--I    I==4==I
     6    I..1..I    I..2..I    I--3--I    I==4==I
     7    I..1..I    I..2..I    I--3--I    I==4==I
     8               I..2..I               I==4==I
```





Mean Chlorophyll a — 1973

Figure 3.4

Mean Chlorophyll *a*, 1974

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

	1	2	3	4	5	6	7	8	9	10
MINIMUM	1.04	2.33	3.62	4.90	6.19	7.47	8.76	10.04	11.33	12.61
MAXIMUM	2.33	3.62	4.90	6.19	7.47	8.76	10.04	11.33	12.61	15.90

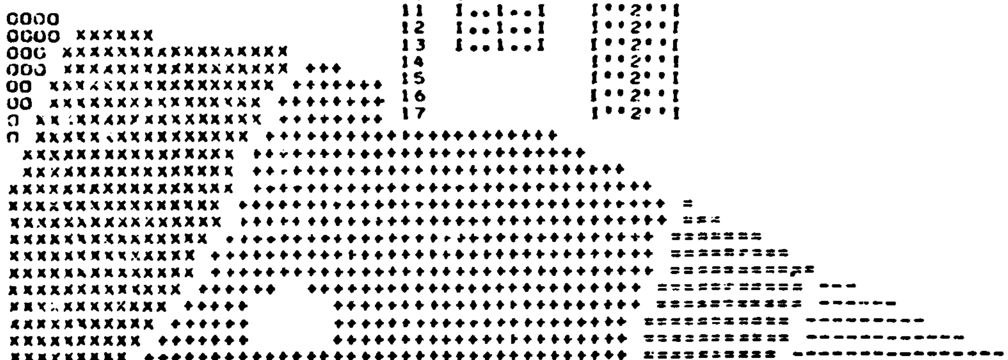
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	....1....	''''2''''	----3----	====4====	++++5++++	XXXX6XXXX	0000700000	8888888888	9	10
FREQ.	13	17	6	1	1	2	1	1	0	1

```
 1  I..1..I  I''2''I  I--3--I  I==4==I  I++5++I  IXX6XXI  I00700I  I8H8H8I          I88*88I
 2  I..1..I  I''2''I  I--3--I                    IXX6XXI
 3  I..1..I  I''2''I  I--3--I
 4  I..1..I  I''2''I  I--3--I
 5  I..1..I  I''2''I  I--3--I
 6  I..1..I  I''2''I  I--3--I
 7  I..1..I  I''2''I
 8  I..1..I  I''2''I
 9  I..1..I  I''2''I
10  I..1..I  I''2''I
11  I..1..I  I''2''I
12  I..1..I  I''2''I
13  I..1..I  I''2''I
14           I''2''I
15           I''2''I
16           I''2''I
17           I''2''I
```



Mean Chlorophyll a — 1974

Figure 3.5

Mean Assimilation Ratio, 1973

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	5.81	7.29	8.77	10.25	11.73	13.21	14.69	16.17	17.65	19.13
MAXIMUM	7.29	8.77	10.25	11.73	13.21	14.69	16.17	17.65	19.13	20.61

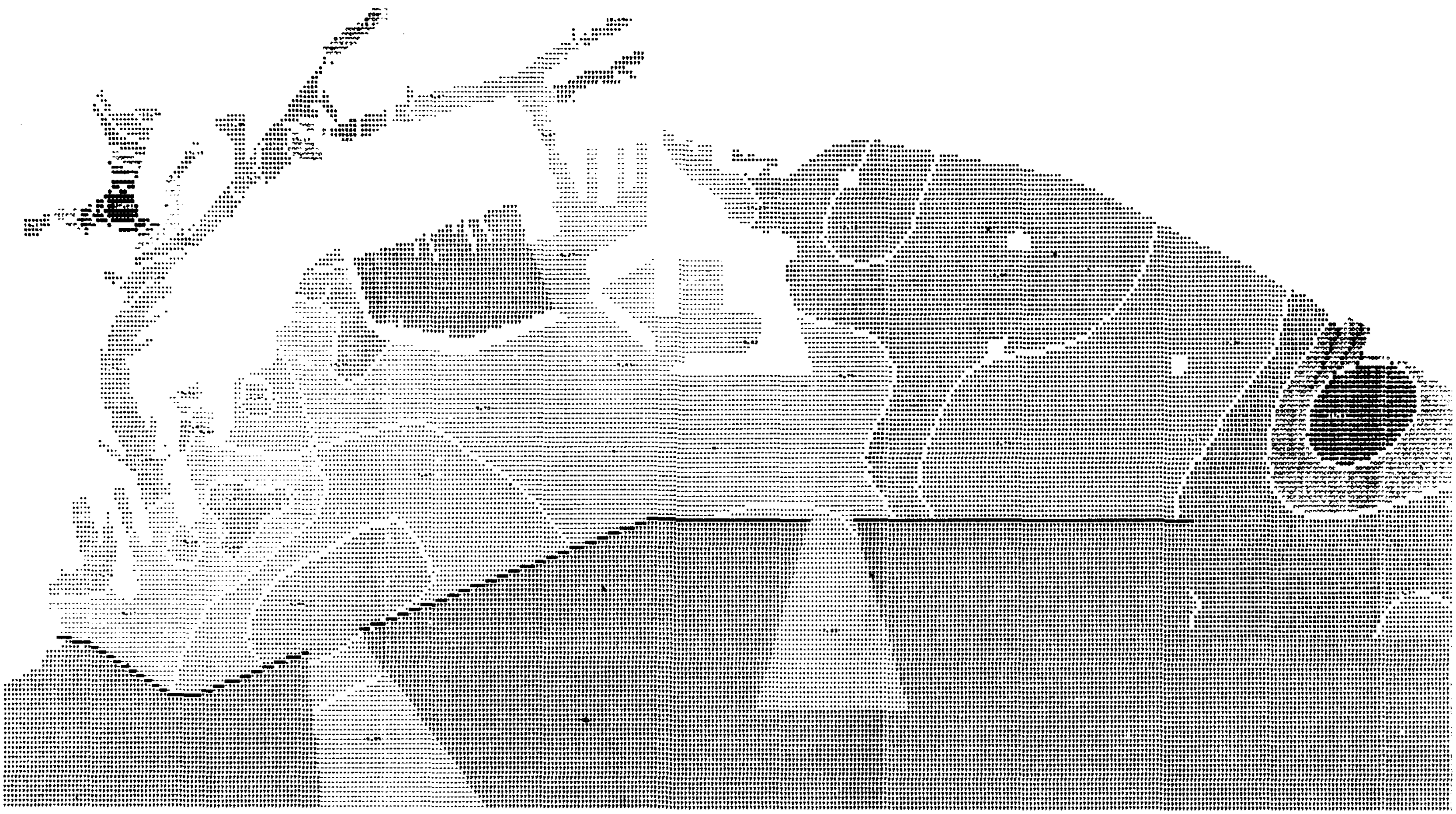
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	....1....	'''2'''	----3----	====4====	++++5++++	XXXX6XXXX	0000700000	8888888888	9999999999	████████
FREQ.	2	4	11	11	6	3	2	1	0	1

```
FREQ.     2          4          11         11         6          3          2          1          0          1
   1  I..1..I   I''2''I   I--3--I   I==4==I   I++5++I   IXX6XXI   I00700I   I88888I              I██*██I
   2  I..1..I   I''2''I   I--3--I   I==4==I   I++5++I   IXX6XXI   I00700I
   3            I''2''I   I--3--I   I==4==I   I++5++I   IXX6XXI
   4            I''2''I   I--3--I   I==4==I   I++5++I
   5                      I--3--I   I==4==I   I++5++I
   6                      I--3--I   I==4==I   I++5++I
   7                      I--3--I   I==4==I
   8                      I--3--I   I==4==I
   9                      I--3--I   I==4==I
  10                      I--3--I   I==4==I
  11                      I--3--I   I==4==I
```



Mean Assimilation Ratio A — 1973

Figure 3.6

Mean Assimilation Ratio, 1974

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

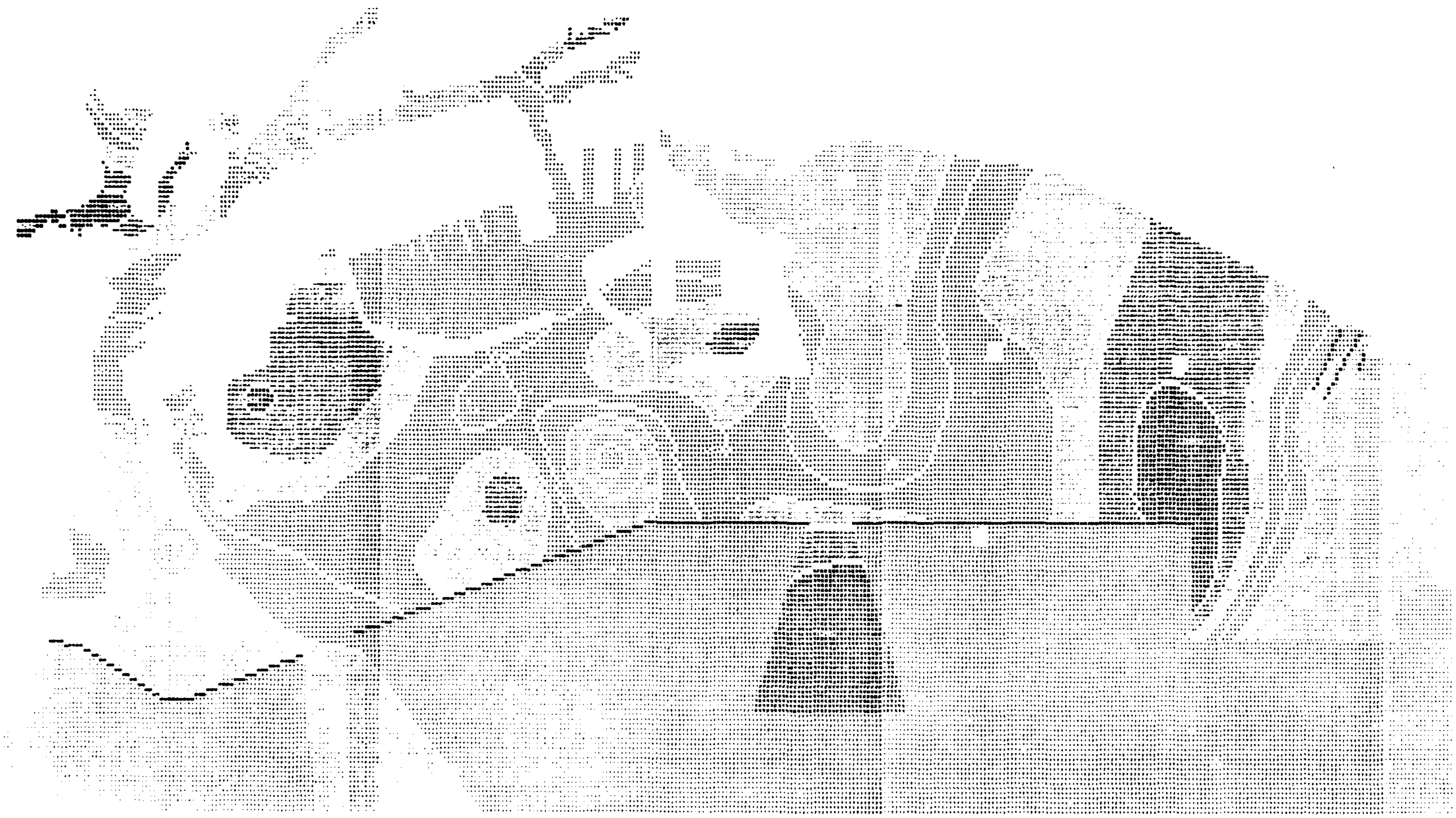
MINIMUM	8.96	9.80	10.64	11.49	12.33	13.17	14.02	14.86	15.70	16.54
MAXIMUM	9.80	10.64	11.49	12.33	13.17	14.02	14.86	15.70	16.54	17.39

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

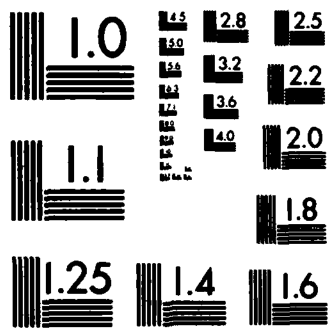
LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	••••1••••	''''2''''	----3----	====4====	++++5++++	XXXX6XXXX	OOOO7OOOO	ØØØØ8ØØØØ	XXXX9XXXX	■■■■■■■■■
FREQ.	2	3	6	5	6	6	4	4	6	1
1	I..1..I	I''2''I	I--3--I	I==4==I	I++5++I	IXX6XXI	IOO7OOI	IØØ8ØØI	IXX9XXI	I■■■■■I
2	I..1..I	I''2''I	I--3--I	I==4==I	I++5++I	IXX6XXI	IOO7OOI	IØØ8ØØI	IXX9XXI	
3		I''2''I	I--3--I	I==4==I	I++5++I	IXX6XXI	IOO7OOI	IØØ8ØØI	IXX9XXI	
4			I--3--I	I==4==I	I++5++I	IXX6XXI	IOO7OOI	IØØ8ØØI	IXX9XXI	
5			I--3--I	I==4==I	I++5++I	IXX6XXI			IXX9XXI	
6			I--3--I		I++5++I	IXX6XXI			IXX9XXI	



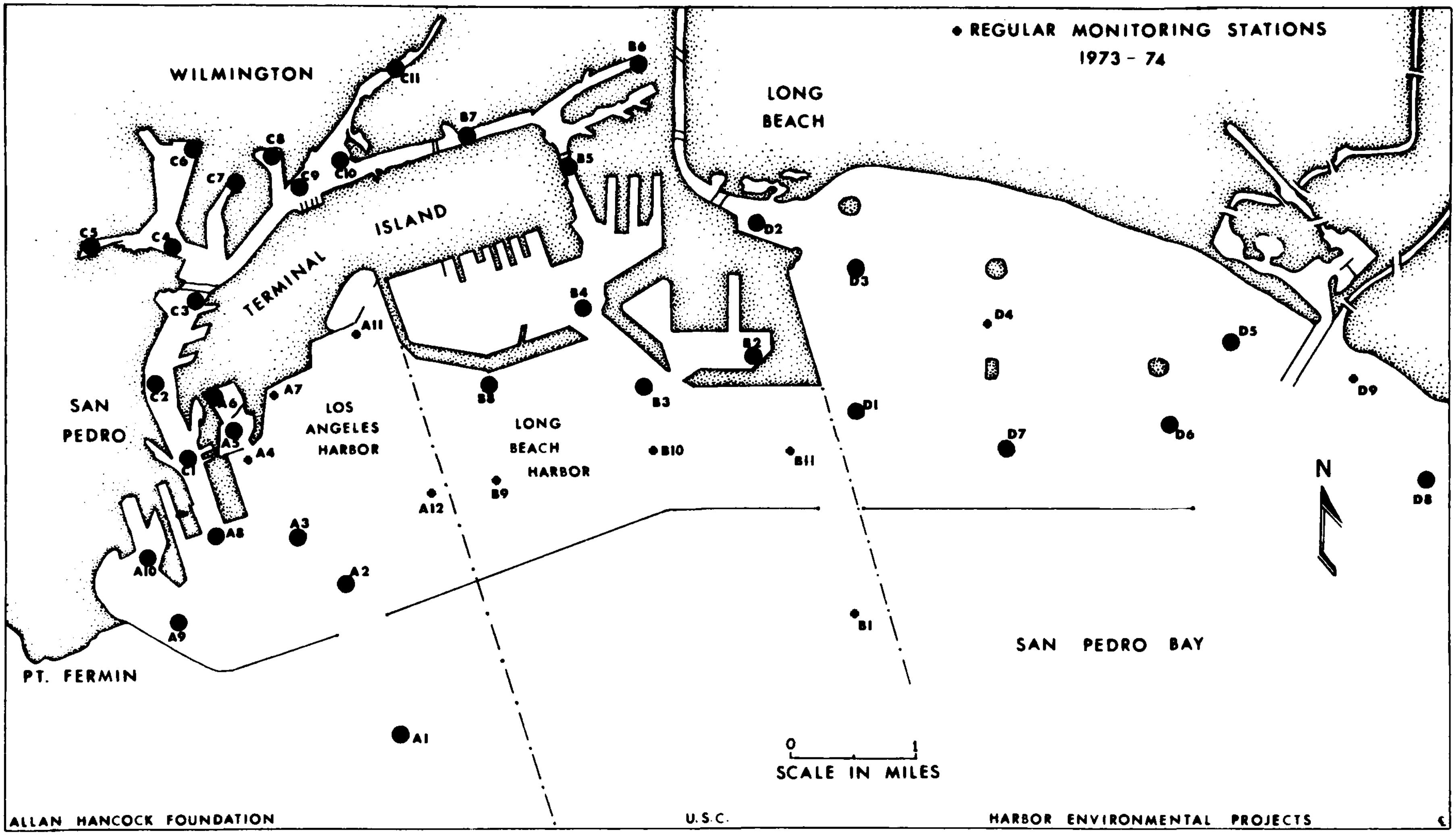
Mean Assimilation Ratio A — 1974
Figure 3.7

AD-A136 653 ENVIRONMENTAL INVESTIGATIONS AND ANALYSES FOR LOS ANGELES-LONG BEACH HARB..(U) UNIVERSITY OF SOUTHERN CALIFORNIA LOS ANGELES ALLAN HANCOCK F.. DEC 76 2/8

UNCLASSIFIED DACW09-73-C-0112 F/G 8/10 NL

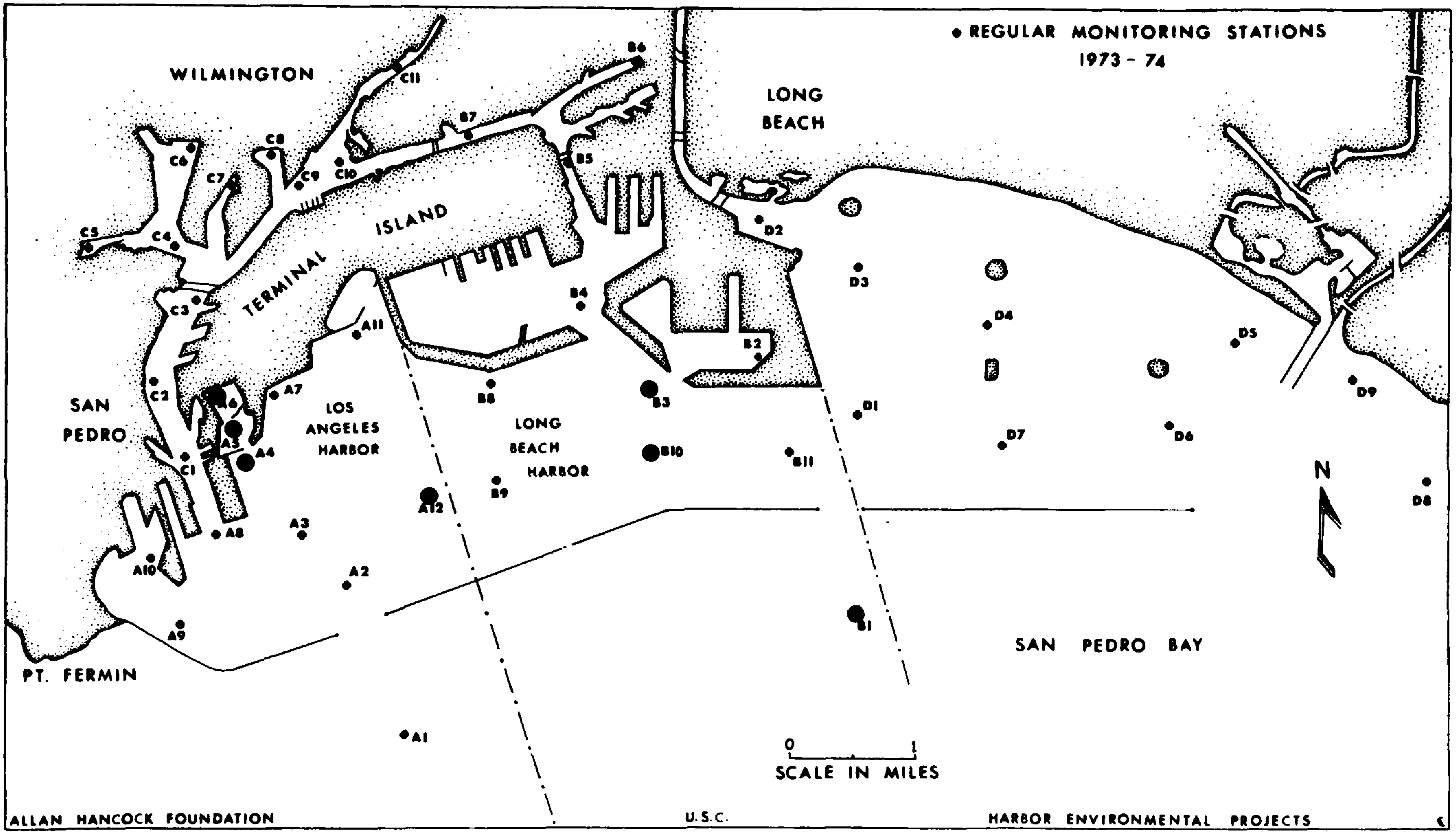


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

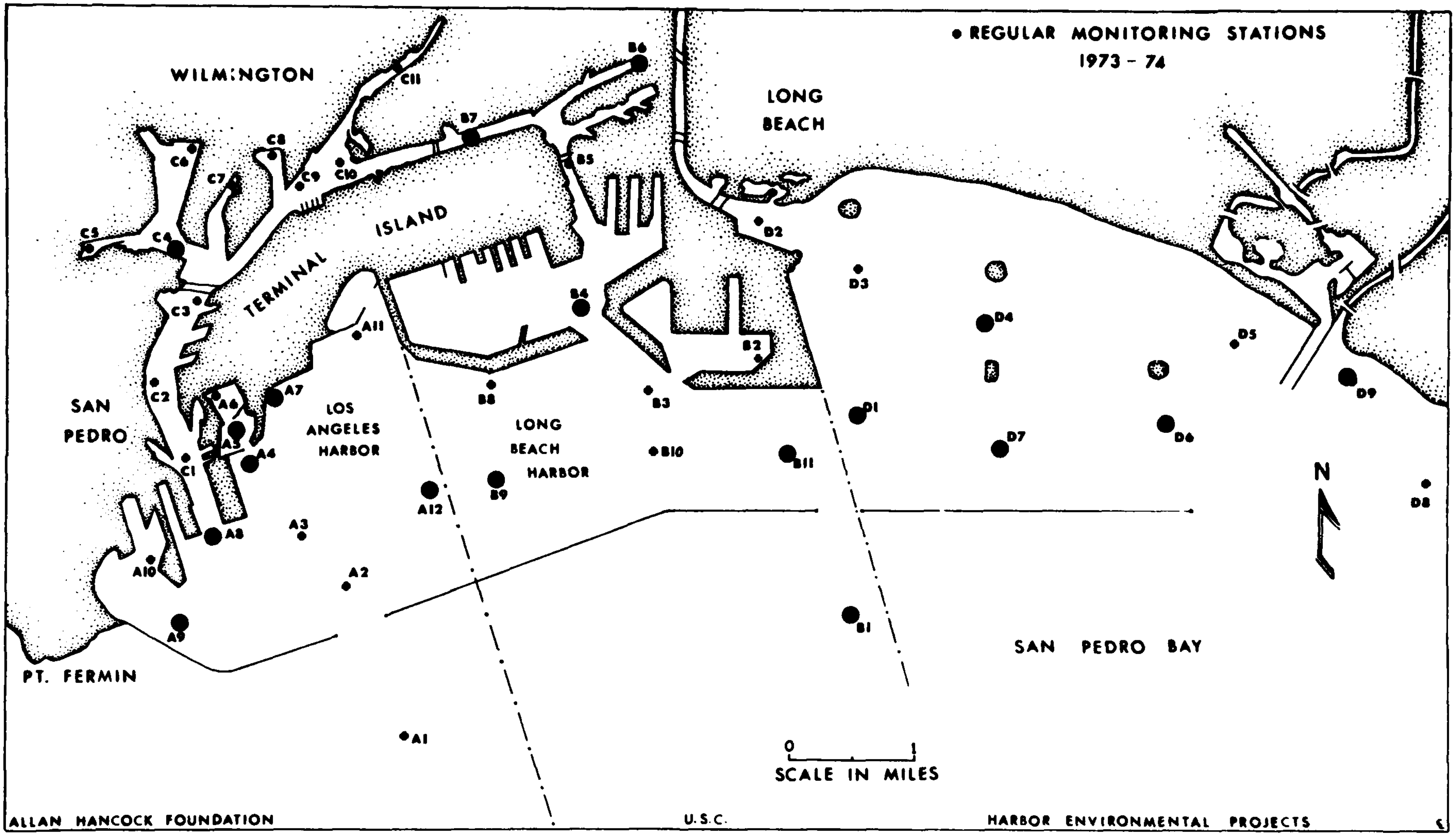


STATIONS WITH SIGNIFICANT CORRELATION COEFFICIENTS BETWEEN CHLOROPHYLL a AND PRODUCTIVITY

Figure 3.8



STATIONS WITH SIGNIFICANT CORRELATION COEFFICIENTS
BETWEEN CHLOROPHYLL a AND ASSIMILATION
RATIO
Figure 3.9



STATIONS WITH SIGNIFICANT CORRELATION COEFFICIENTS BETWEEN PRODUCTIVITY AND ASSIMILATION RATIO

Figure 3.10

Chapter 4

ZOOPLANKTON DISTRIBUTION AND SEASONALITY

4.1

ZOOPLANKTON DISTRIBUTION AND SEASONALITY

INTRODUCTION

Planktonic organisms are those that are permanently or temporarily suspended in a water mass, and subject to transport by circulation patterns. Although some are able to swim, the organisms generally are not large enough or strong enough to swim any significant distance. Included in the zooplankton are numerous tiny crustaceans called copepods, which furnish food for many fish and invertebrates, plus the eggs, larvae and some juveniles of other crustaceans, molluscs, polychaete worms, ectoprocts, hydroids, and fish.

The zooplankton of the California coastal waters have been studied extensively in the past as exemplified by the many years that the California Cooperative Oceanic Fisheries Investigations sampled and studied the waters of the California Current. Of the waters nearshore, Essenberg (1926) and Esterly (1905, 1912, 1930) worked extensively off the San Diego coast. Coastal waters to the north were studied by Esterly (1924) and Painter (1966) in the San Francisco Bay area, and Baker (1938) in Monterey Bay.

With the amount of oceanographic work done off the California coast, it is surprising to note that virtually no planktonic research had been conducted in the Los Angeles-Long Beach Harbors prior to the present study. Because of this void, it was essential to start research toward establishing baseline information on zooplankton populations of the harbors.

The objectives of this research were multiple. First, the distributional patterns of zooplankton were studied, on a gross basis comparing and contrasting zooplankton associations found with the geographic localities of the harbors, and on a finer basis associated with points of particular interest, such as areas of chemical pollution, or eutrophication. The effect of seasons on the zooplankton population and distribution, and the degree of diversity within the harbors were all investigated. Seasonal (temporal) distribution is discussed on p. 4.9.

METHODS

Surface zooplankton collections were taken aboard the University of Southern California research vessel Golden West, using a half-meter, .253 u mesh nylon, conical plankton net. The net was towed at about one knot for five to ten minutes, with a flow meter positioned between the center and the rim of the

mouth to record the volume of water flowing through the net. Plankton samples were placed in liter jars and preserved in formalin.

The sampling stations consisted of four series, A through D, each being sampled monthly. After sampling only the A series during 1972, the sampling program was expanded to include A through D, which was sampled from 1973 through 1974.

Identification and counting of the samples was preceded by determining settling volumes, and subsampling with a Folsom plankton splitter such that the aliquots contained approximately 500 to 1,000 organisms. All 1972 samples were counted; however, because of the volume of samples and data and time limitations, the four series per month from 1973 through 1974 were analyzed quarterly, i.e., February, May, August, and November on a regular basis with additional counts of the A series, located in the area of proposed dredge and fill.

Plankton counts were entered and stored on computer tapes in the form of individuals per species per cubic meter (Condap, pers. comm.). Computer programs developed by R. Smith (pers. comm.) were used in the analysis of this data.

DISCUSSION

The zooplankton in the Los Angeles-Long Beach Harbors is dominated by crustaceans, especially the calanoid copepod, *Acartia tonsa*, whose mean numbers amount to 50% of all plankton animals. There are no other organisms in the zooplankton of the harbor which approximate this degree of dominance. Next in abundance are the cladocerans, *Podon polyphemoides*, 11%, and the copepod *Paracalanus parvus*, 10%. At 4.7% is the cladoceran *Evadne nordmanni*, and the copepod, *Corycaeus anglicus* makes up 1.6%. These five can be considered as the dominant zooplankton species in the harbors. Other abundant organisms are Larvacea and barnacle nauplii, at approximately 5% each. The remainder, less than 5%, is made up of small proportions of other organisms as listed in Table 4.1. These less abundant organisms are found either in consistently low abundance or only occasionally in greater numbers.

Spatial Distribution

The distribution of the dominant zooplankters divide the harbor generally into two parts: the inner harbor and the outer harbor. The inner harbor is represented by the C stations and certain of the B stations, B4 through B7. The rest of the sampling stations are considered to be outer harbor stations, although there are considerable differences among some of them.

The zooplankton of the inner harbors is characterized

Table 4.1. RELATIVE ABUNDANCE OF ZOOPLANKTON SPECIES IN THE LOS ANGELES-LONG BEACH HARBORS.

	Mean Concentration (per cubic meter)	Proportion of Plankton
Acartia tonsa	1537.60	57.88%
Podon polyphemoides	294.53	11.09%
Paracalanus parvus	265.94	10.01%
Larvaceans	152.18	5.73%
Evadne nordmanni	124.82	4.70%
Barnacle Nauplii Larvae	110.13	4.15%
Corycaeus anglicus	41.90	1.58%
Labidocera trispinosa	22.99	0.86%
Oithona oculata	15.28	0.57%
Crab Zoea Larvae	12.62	0.47%
Oithona similis	11.38	0.43%
Medusae	7.07	0.27%
Chaetognaths	5.31	0.20%
Fish Eggs and Larvae	5.03	0.19%
Calanus helgolandicus	4.20	0.16%
Tunicate Tadpole Larvae	4.19	0.16%
Gastropod Veliger Larvae	3.37	0.13%
Bryozoan Cyphonautes Larvae	3.31	0.12%
Ophiuroid Pluteus Larvae	2.85	0.11%
Polychaete Trochophore Larvae	2.40	0.09%
Siphonophores	2.38	0.09%

Table 4.1. (cont'd)

	Mean Concentration (per cubic meter)	Proportion of Plankton
Harpacticoid Copepods	2.25	0.08%
Euterpina acutifrons	1.45	0.05%
Penilia avirostris	1.33	0.05%
Ctenocalanus vanus	1.14	0.04%
Euphausids	0.91	0.03%
Holothuroid Auricularia Larvae	0.63	0.02%
Acartia clausi	0.50	0.02%
Oithona spinirostris	0.40	0.02%
Tortanus discaudatus	0.39	0.01%
Pelecypod Veliger Larvae	0.34	0.01%
Nematodes	0.31	0.01%
Clausocalanus furcatus	0.29	0.01%
Doliolids	0.28	0.01%
Rhincalanaus nasutus	0.21	<0.01%
Isopods	0.18	<0.01%
Calocalanus styliremis	0.17	<0.01%
Clausocalanus parapergens	0.11	<0.01%
Evadne spinifera	0.10	<0.01%
Pseudodiatomus euryhalinus	0.07	<0.01%
Labidocera jollae	0.07	<0.01%
Oithona plumifera	0.05	<0.01%

4.5

Table 4.1. (cont'd)

	Mean Concentration (per cubic meter)	Proportion of Plankton
Corycaeus amazonicus	0.05	< 0.01%
Gammarid Amphipods	0.05	< 0.01%
Clausocalanus farrani	0.04	< 0.01%
Ctenophores	0.04	< 0.01%
Calocalanus tenuis	0.02	< 0.01%
Candacia curta	0.02	< 0.01%
Clausocalanus arcuicornis	0.01	< 0.01%
Acartia danae	0.01	< 0.01%
Mecynocera clausi	0.01	< 0.01%
Microsetella rosea	< 0.01	< 0.01%
Temora discaudata	< 0.01	< 0.01%
Caprellid Amphipods	< 0.01	< 0.01%
Microsetella norvegica	< 0.01	< 0.01%
Echinoid Pluteus Larvae	< 0.01	< 0.01%

by high concentrations of *Acartia tonsa* (Figure 4.1) and the cyclopoid copepod, *Oithona oculata* (Figure 4.2). This is concommitant with a decrease in the abundance of other members of the zooplankton, most notably the two major cladocerans, *Podon polyphemoides* (Figure 4.3) and *Evadne nordmanni* (Figure 4.4) , and a minor one, *Penilia avirostris* (Figure 4.5). Such decreases also occur in important planktonic larvae of fish and bryozoans, and fish eggs (Figure 4.6). The paucity of cladocerans in this area is particularly striking; *Podon polyphemoides, Evadne nordmanni,* and *Penilia avirostris* are, respectively, 10, 100, and 1,000 times less abundant in the inner harbor than in the outer harbor. The result is that the inner harbor fauna is more than 75% *Acartia tonsa*.

As might be expected, environmental conditions in the inner harbor are different from those in the outer harbor. The strongest and most consistent differences, as indicated by discriminant analysis techniques are in pH and dissolved oxygen. The inner harbor has a low pH (7.75) and dissolved oxygen (6.1 ppm) while the outer harbor has a higher mean pH (8.02) and dissolved oxygen (8.0 ppm). While these two parameters may be the most important, other water characteristics are also different in the two areas of the harbor. There is a lower mean salinity and less salinity variation in the inner harbor, but a higher mean temperature, as compared with the outer harbor.

Stations B4 through B7 represent an area of apparent overlap between inner and outer harbor fauna. *Acartia tonsa* is abundant, but so are *Podon polyphemoides* and *Evadne nordmanni*. Even fish eggs and larvae, so dramatically absent from the "C" stations, are found in this sector. This may be because pH, oxygen, salinity, and temperature conditions here are intermediate to those of the inner and outer harbors. The only species which does not appear to respond strongly to the different conditions in the inner and outer harbor is *Paracalanus parvus*. This species' concentration is very similar everywhere, with only a slightly greater abundance in the "B" stations.

Some species appear to prefer certain areas of the outer harbor to others. *Penilia avirostris* (Figure 4.5) is nearly 10 times more abundant in the "A" stations, whose most conspicuous attribute is the highest salinity variation in the harbor, and the presence of the sewer and cannery wastes. The B stations have nearly four times the numbers of barnacle nauplii (Figure 4.8) as the rest of the outer harbor, while Larvacea (Figure 4.9) are well distributed throughout the outer harbor, but appear in highest numbers in the "D" stations.

When the total zooplankton concentration is considered (Figure 4.10), the near exclusion of Cladocera from the

inner harbor and increased abundance of *Acartia tonsa* there are compensatory; the total zooplankton concentrations in the two areas are roughly similar. Only the "B" stations are markedly higher in zooplankton. This may be due to the overlapping of ranges occurring in the area of stations B4 through B7.

Two obvious characteristics of biological assemblages are the number of kinds of organisms represented and the proportions of each. Areas with many kinds of organisms, similar in abundance, are called high diversity communities, while those with few kinds of organisms or a few dominant ones are called less diverse. Though this parameter is difficult to quantify, certain indices have been used. One such index, suggested by Longhurst (1967) is the percentage of the plankton represented by the two most abundant species. Diversity has also been related to the stability of the community (MacArthur, 1955). On this basis, the inner harbor possesses a lower diversity and a less stable zooplankton community, while the outer harbor is more diverse and more stable. The open coast, represented by stations A1 and B1, outside the breakwater, is the most diverse and stable of all.

Within the broad areas of the harbor already discussed are a number of smaller sections of particular biological importance because their plankton is different from the plankton of the larger area around them.

Warm water is discharged from the Union Oil Refinery and the Harbor Steam Plant near station C6. Oil slicks and chemical leaks have also been intermittent in this semi-enclosed basin. This coincides with particularly low zooplankton abundance. Even the dominant *Acartia tonsa* is affected (Figure 4.1). The warm discharge also influences the water temperature at stations C4 and C5, although C5 is in shallower, naturally warmer water. *Podon polyphemoides* and *Corycaeus anglicus*, two species which appear sensitive to the prevailing conditions of the C stations, are found in particularly low numbers. This may be related to elevated metabolic rates in these animals which would be attendant to areas of higher temperatures, in turn making obtaining sufficient oxygen more difficult. However, these two species also occur in markedly reduced abundance at station C7, where the water is not warmed. Chemical discharges and oil slicks in that area may also be influencing the populations in the dead-end channels.

Warm, fresh water is also being discharged at station D9, as a result of the operation of the Los Alamitos Haynes Power Station. This raises the water temperature considerably, to a mean surface temperature of 20.3^{o} C., some 4^{o} C warmer than the rest of the harbor. There is also a decrease in salinity. Probably as a result, the two major Cladocera, *Podon polyphemoides* (Figure 4.3) and *Evadne nordmanni* (Figure 4.4)

are in sharply lower abundance here. *Podon polyphemoides* is nearly three times less abundant and *Evadne nordmanni* more than 10 times less abundant than at the nearby station, D5, D6, and D8.

Fresh water also enters the harbor from the Dominguez Channel near station C11, resulting in very little zooplankton near that station. Both *Podon polyphemoides* (Figure 4.3) and *Corycaeus anglicus* (Figure 4.11) are found in exceptionally low numbers in this area.

Another freshwater influx occurs from the Los Angeles River near staion D2. Here, *Evadne nordmanni* (Figure 4.4) is the major species affected, although the copepod, *Labidocera trispinosa*, also occurs in low numbers there.

Fresh water is also an element of the fish cannery waste and sewage effluent released near station A7. However, the other constituents of these discharges appear to overshadow any effects of the fresh water. The zooplankton are, in fact, more numerous here than at any of the stations immediately nearby, and *Evadne nordmanni* (Figure 4.4) is more than double its concentration at A7 when compared to adjacent stations. It appears, however, that the effluents have an impact on the surrounding "A" stations, since the zooplankters are in markedly lower concentration at stations immediately surrounding A7 than at those farther away. Evidence of nutrient enrichment at station A7 consists of a high level of ammonia, and BOD, and low dissolved oxygen and water clarity. The ammonia level is 10 times higher than at any of the surrounding stations. It is possible that the particulate matter at A7 is being eaten by zooplankton, but that the smaller and dissolved constituents of the effluents are being swept to nearby areas, providing substrates for bacterial degradation of organic matter. This is consistent with the lower dissolved oxygen and elevated BOD values found in these areas. Again, oxygen seems to be an important determinant of the zooplankton.

High nutrient levels, specifically ammonia and nitrate are found at stations B5 through B7, with B6 being the highest of the three. These may be introduced by the manufacturing plants and effluents in the area. As might be expected, productivity is very high here (90 mg C/m^3 at B6) and the zooplankton is very dense. Notable are the high concentrations of *Corycaeus anglicus* (Figure 4.11) and *Oithona oculata* (Figure 4.2) and the reduced concentrations of the cladocerans *Podon polyphemoides* (Figure 4.3) and *Evadne nordmanni* (Figure 4.4) at B6. The reduced concentration of *Evadne nordmanni*, however, is inconsistent with the elevated concentrations at station A7, suggesting that ammonia or nitrate may not be the limiting factor for that species.

Temporal Distribution (Seasonality)

Figures 4.12 to 4.16 represent the mean temporal abundance of the five dominant zooplankton species for the years 1972 through 1974. While the figures for 1972 are presented monthly, they represent the mean of the A stations only. In 1973 and 1974, the data represent a mean of all stations in the harbor. The data for these last two years represent species identifications from aliquots of quarterly sampling throughout the year. In 1973 and 1974 the A station values were generally reflective of seasonal values found in the whole harbor, so it is likely that the data for 1972 are comparable to the data for the entire harbor from 1973 and 1974. Settling volumes were calculated on a monthly basis.

The copepods *Acartia tonsa* (Figure 4.12), *Paracalanus parvus* (Figure 4.13), and *Corycaeus anglicus* possess the same general seasonal pattern: high abundance in the winter months and low in the summer months. Some intermittant peaks in abundance occur, particularly in the spring, but not on a regular basis. These data differ from Esterly's (1930) results on *Acartia tonsa* and *Paracalanus parvus*. He found *Acartia tonsa* to be most abundant in the summer, and least abundant in February. While his data on *Paracalanus parvus* are quite variable, low abundances occurred in February of his two sampling years. This study, however, showed that February had the highest numbers for this species in two of the three sampling years.

The cladocerans, *Podon polyphemoides* (Figure 4.15) and *Evadne nordmanni* (Figure 4.16) show evidence of the same sort of pattern, particularly in the low summer abundances, but there is much more variation. These two were in particularly great abundance in the spring of 1972, and never quite duplicated these concentrations again. Baker (1938) found these species to occur throughout the year in Monterey Bay. She indicated that *Podon polyphemoides* occurred in greatest numbers during the winter, but that *Evadne nordmanni* was most abundant in May with fewest occurring in winter. This study showed similar results in some respects. Both species were present throughout the year and *Podon polyphemoides* had a minor peak in the fall and winter of 1973. The greatest abundance of *Podon polyphemoides*, however, was in the spring of 1972. The spring maxima of *Evadne nordmanni* reported by Baker (1938) was also observed in the harbor, but this occurred only once during the three year sampling period.

Figure 4.17 represents the relative contributions these species make to the total zooplankton. The zooplankton abundances and variations in abundance can be principally attributed to the concentrations of these five species.

Biotic-Abiotic Interactions

The distribution and seasonality of zooplankton are determined to a large extent by multiple abiotic parameters which interact as limiting factors. Figures 4.18-4.21 illustrate the effects of various abiotic factors on the distribution of selected plankton, according to the season (February, May, August, and November, 1974). Weighted discriminant analysis techniques make possible the comparison of a number of species and parameters simultaneously. In the cases presented, the species *Acartia tonsa* was eliminated from the analysis because it dominates the numbers so greatly as compared with other species; it constitutes 58% of the plankton sampled and is especially prolific in the inner Long Beach Harbor (Figure 4.1).

IMPACT

Long Term Impacts

The long term impact of the proposed master plan for the harbor on zooplankton is difficult to predict because so many variables will be altered which cannot be tested in advance. Nevertheless, some general predictions can be reasonably made at this time.

The filling of much of the outer harbor will decrease the total zooplankton content of the outer harbor simply by eliminating much of the open water area.

With the restrictions in circulation of the outer harbor which would occur consequent to such a filling, it is likely that outer harbor conditions would shift toward conditions ordinarily found in the inner harbor. If this occurred, there would probably be a major shift in the species make-up of the zooplankton in the outer harbor. The Cladocera, which are so intolerant of inner harbor conditions, would greatly decrease in abundance, with an unknown effect on the food web. The same would be true of fish eggs and larvae, which might be more important to the total ecology of the area than changes in zooplankton composition might be, unless the species are those which are found to be essential to the diet of the fish. On the other hand, species dominant in the inner harbor at present would tend to become more abundant in outer harbor waters. These species include the dominant zooplankter *Acartia tonsa* and the cyclopoid, *Oithona oculata*.

These changes would not necessarily alter the total zooplankton concentration in the outer harbor. They could, however, alter the existing food web there.

Short Term Impacts

Since the zooplankton appears to be sensitive to levels of dissolved oxygen, dredging activities which would disturb anoxic sediments and distribute them throughout the water would probably temporarily affect the zooplankton in those areas dredged. All species would probably suffer great losses in numbers. Unfortunately, information on which to judge how long this effect would last, or how extensive an area would be affected is not available for the local harbor sediments. Krenkel, Harrison and Burdick (1976) presented a number of discussions on dredging effects. Those and other papers indicate that the larval stages, which would include meroplankton, are the most sensitive to environmental disturbance.

LITERATURE CITED

Baker, H. 1938. Studies on the Cladocera of Monterey Bay. Proc. Calif. Acad. Sci. 23(23):311-365.

Essenberg, C.E. 1926. Copelata from the San Diego region. Univ. Calif. Pub. Zoology 28(22):399-521.

Esterly, C.O. 1905. The pelagic Copepoda of the San Diego region. Univ. Calif. Pub. Zoology 2(4):113-233.

------------. 1912. The occurance and vertical distribution of the Copepoda of the San Diego region. Univ. Calif. Pub. Zoology 9:253-340.

------------. 1924. The free swimming Copepoda of San Francisco Bay. Univ. Calif. Pub. Zoology. 26(5):81-129.

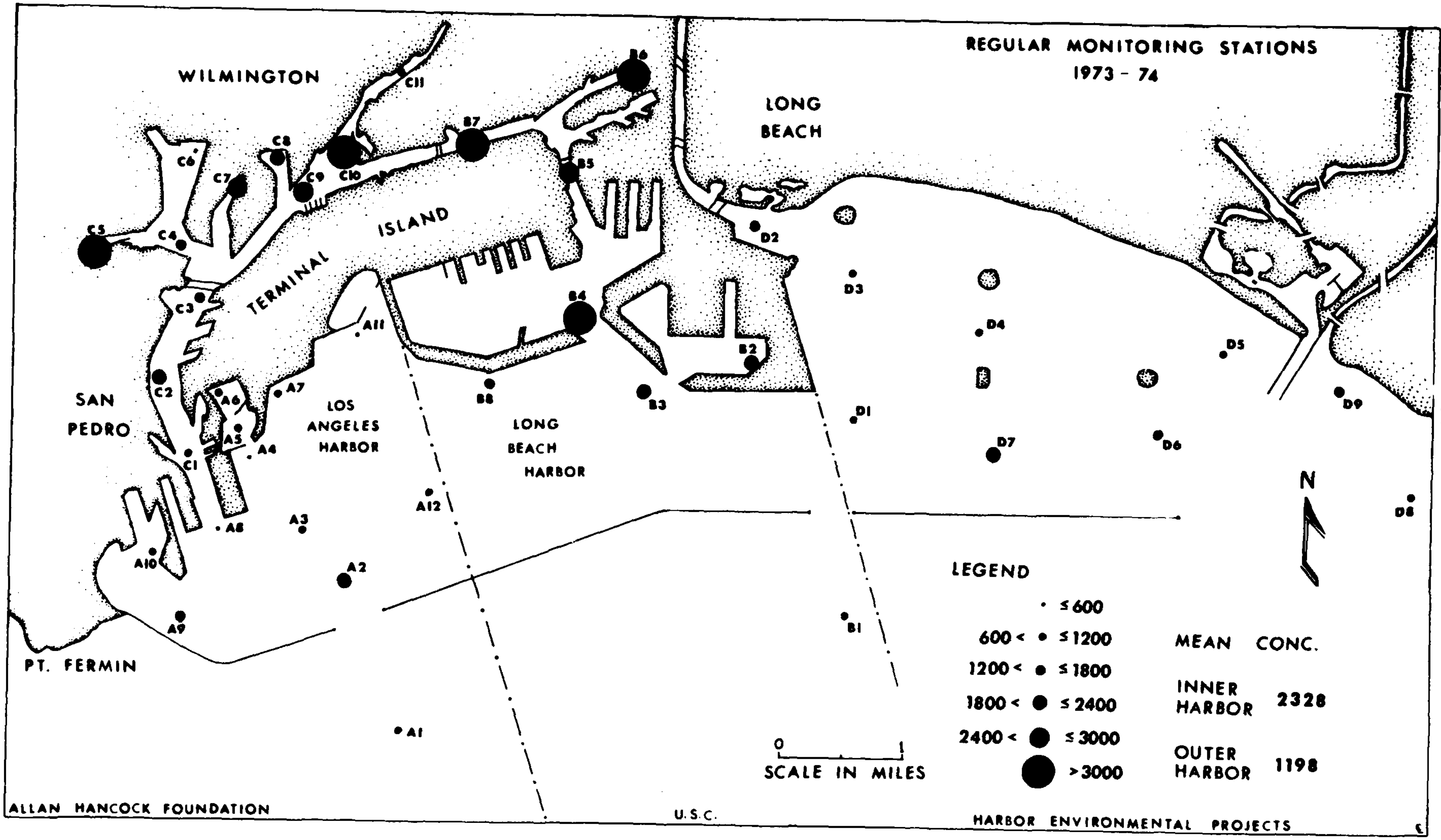
------------. 1930. The periodic occurance of Copepoda in the marine plankton of two successive years at La Jolla, California. Bull. Scripps. Inst. Oceanogr., Univ. Calif. Tech. Ser. 1(14):247-345.

Krenkel, P.A., J.Harrison, and J.C.Burdick III, (eds.). 1976. Dredging and its environmental effects. Proc. Specialty Conf. Amer. Soc. Civ. Engineers. 1037 p.

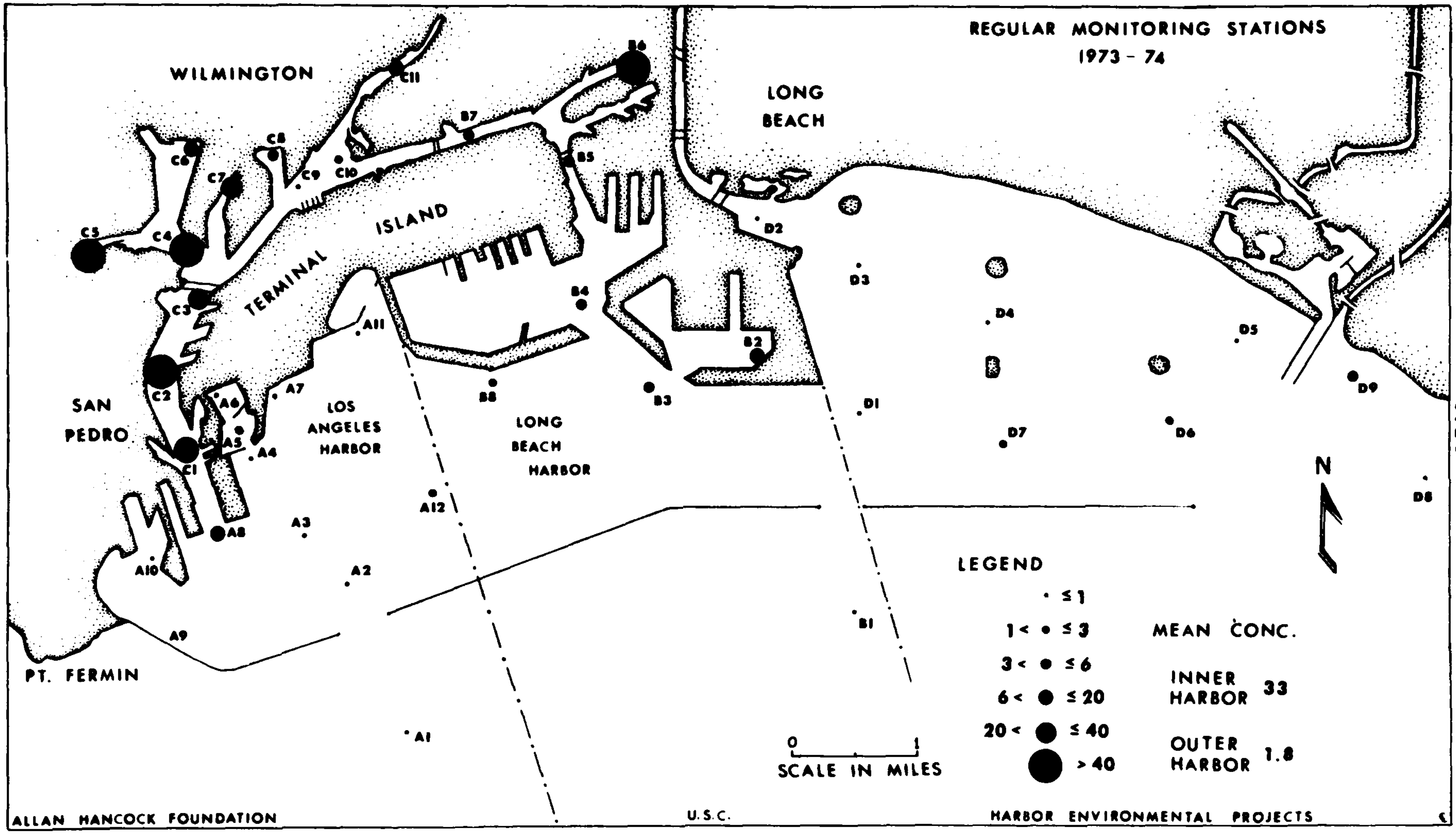
Longhurst, A.R. 1967. Diversity and trophic structure of zooplankton communities in the California Current. Deep Sea Research 14:393-408.

MacArthur, R. 1955. Fluctuations of animal populations and a measure of community stability. Ecology 36:148-151.

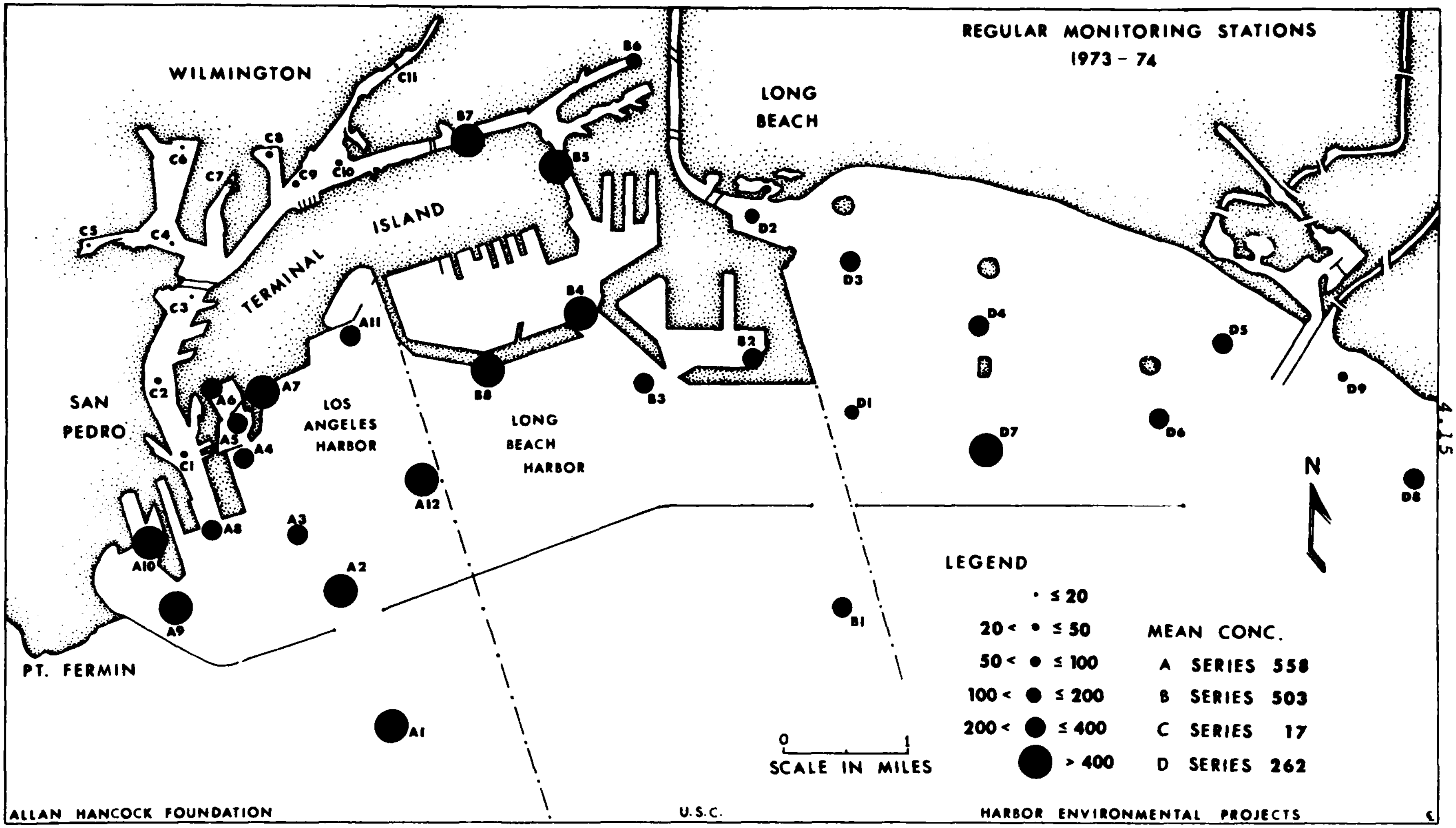
Painter, R.E. 1966. Ecological studies of the Sacramento-San Joaquin Estuary. Zooplankton of San Pablo and Suisan Bays, Calif. Dept. Fish. Game Bull. 133:18-39.



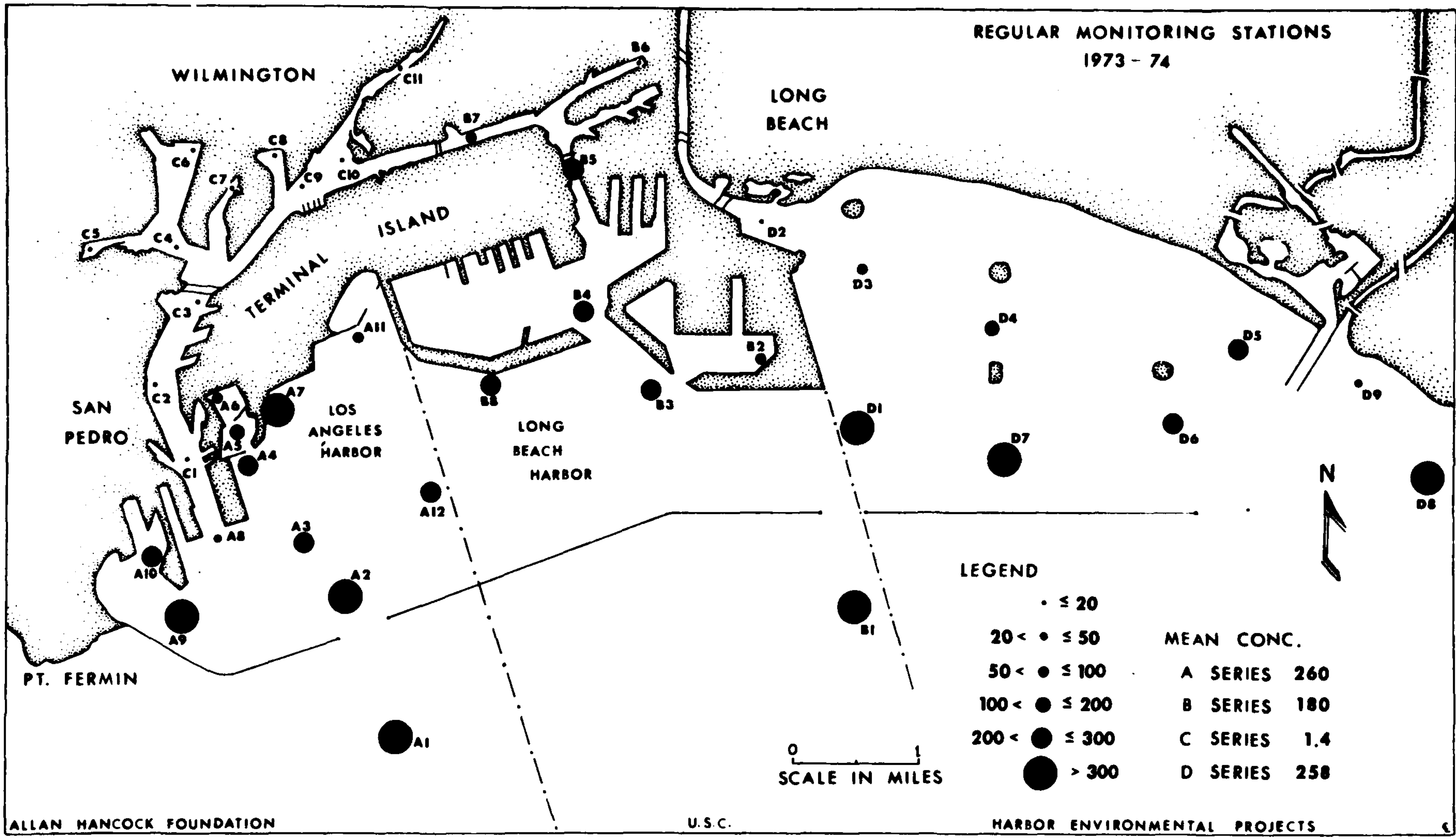
MEAN SPATIAL DISTRIBUTION OF *Acartia tonsa*
Figure 4.1



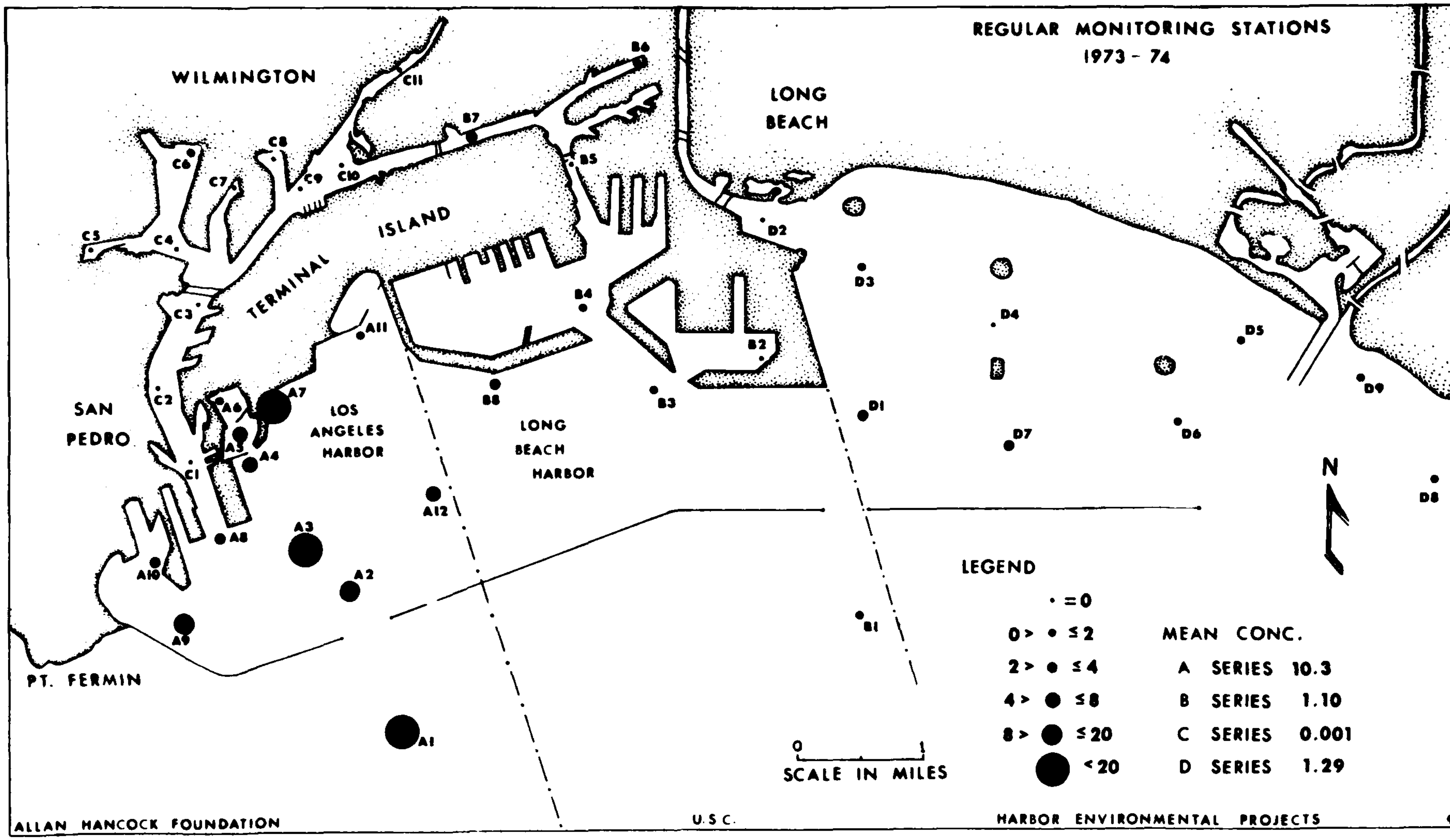
MEAN SPATIAL DISTRIBUTION OF *Oithona oculata*
Figure 4.2



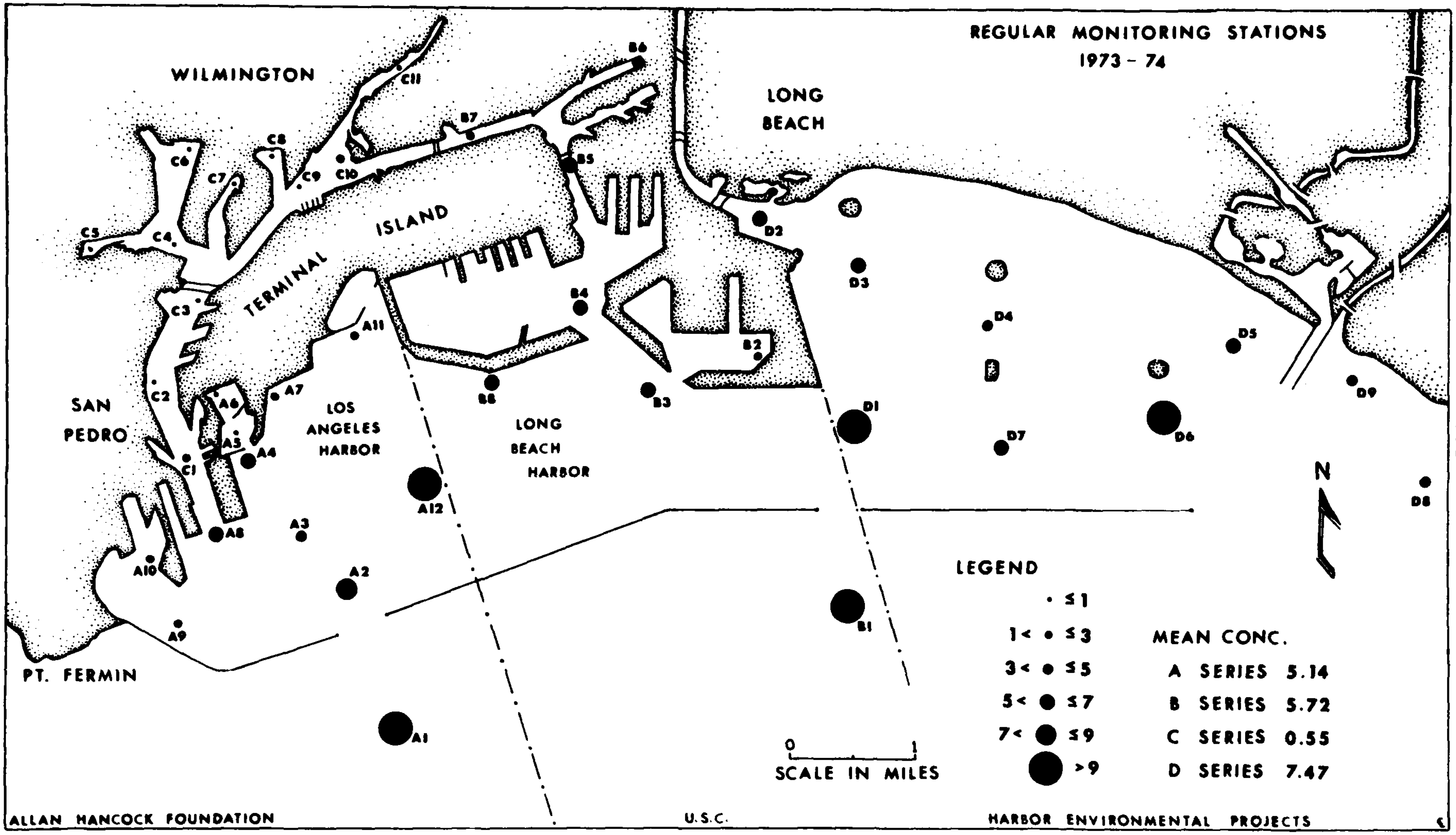
MEAN SPATIAL DISTRIBUTION OF *Podon polyphemoides*
Figure 4.3



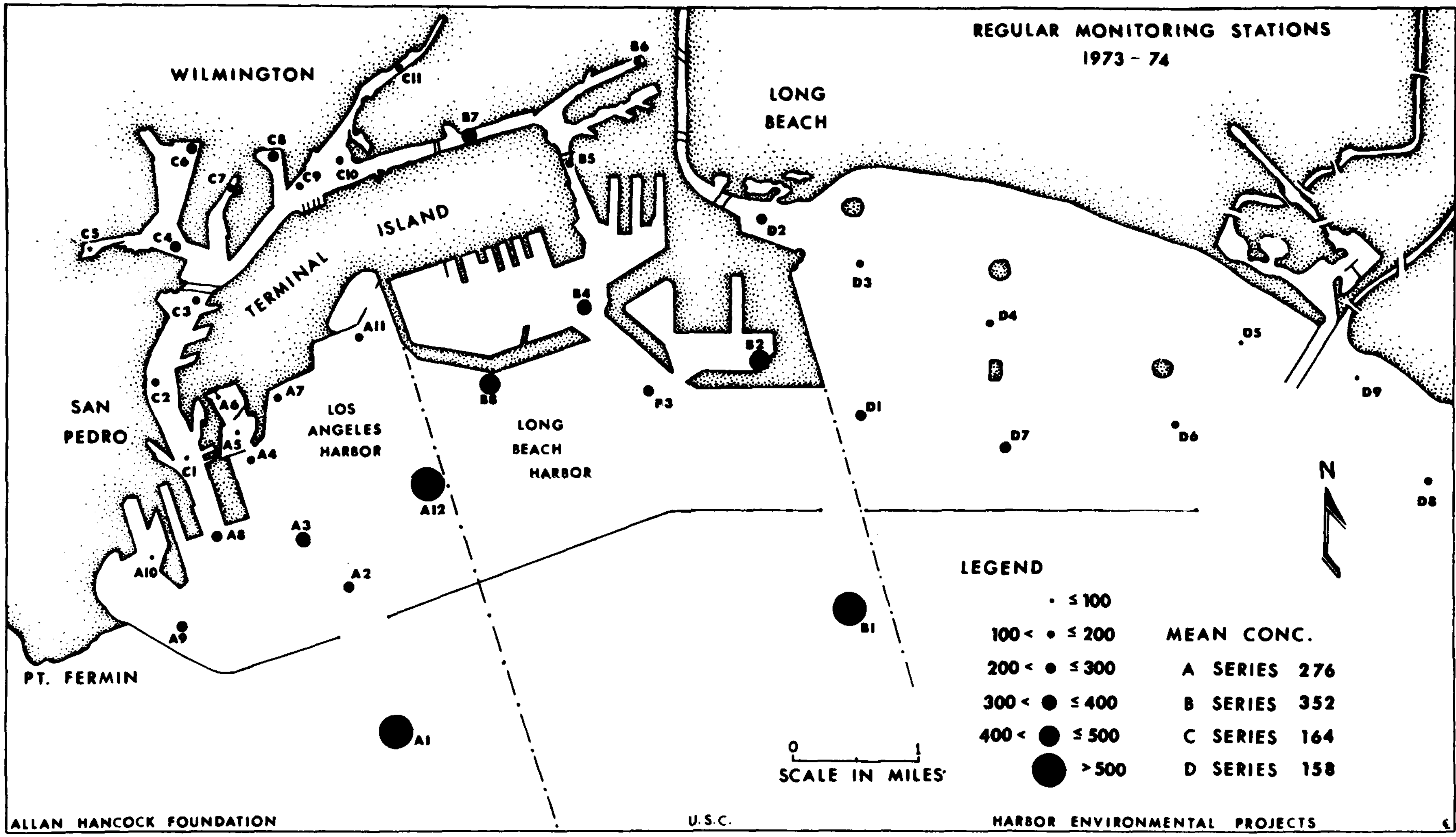
MEAN SPATIAL DISTRIBUTION OF *Evadne nordmanni*
Figure 4.4



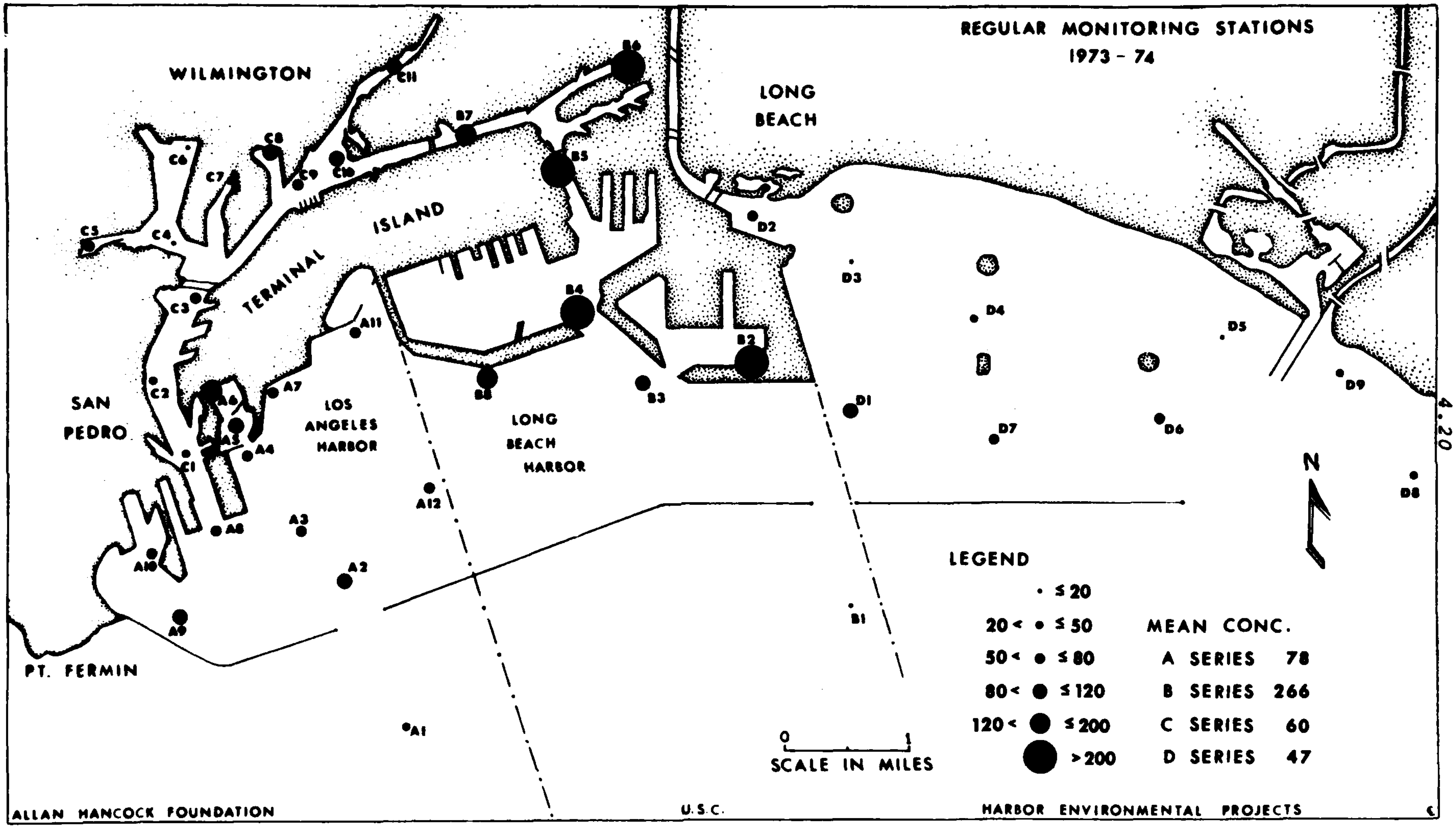
MEAN SPATIAL DISTRIBUTION OF *Penilia avirostris*
Figure 4.5



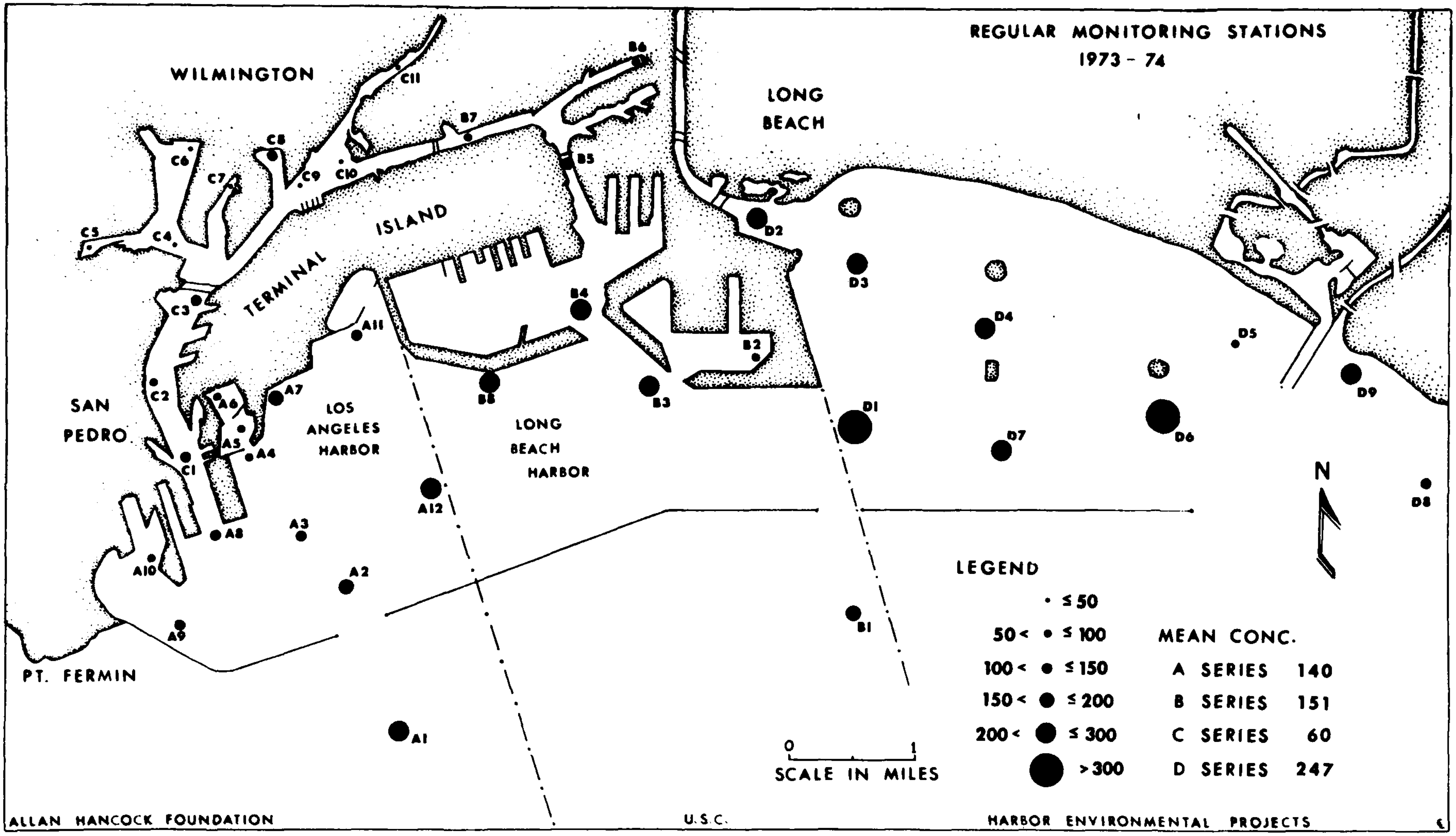
MEAN SPATIAL DISTRIBUTION OF
FISH EGGS AND LARVAE
Figure 4.6



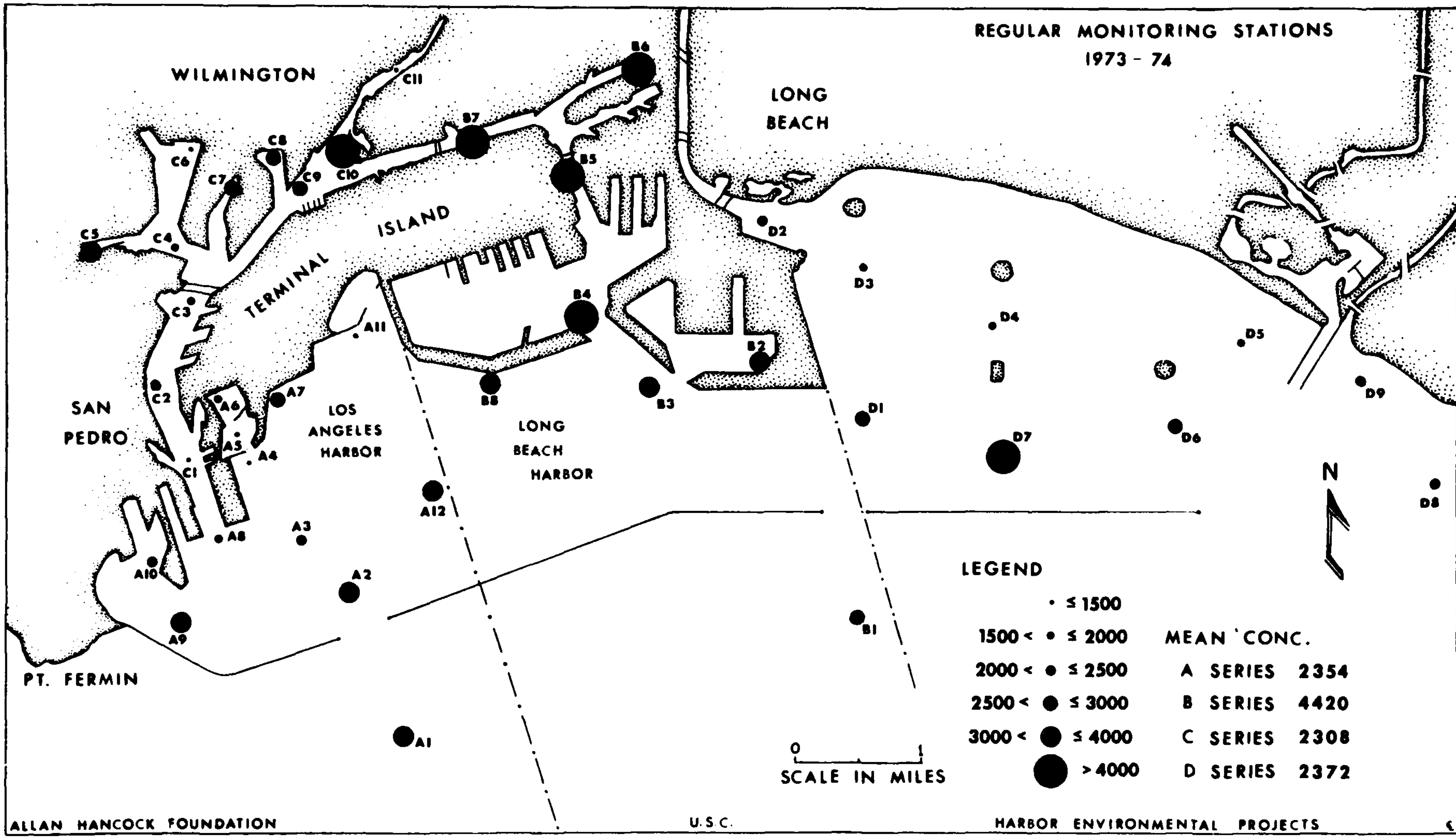
MEAN SPATIAL DISTRIBUTION OF *Paracalanus parvus*
Figure 4.7



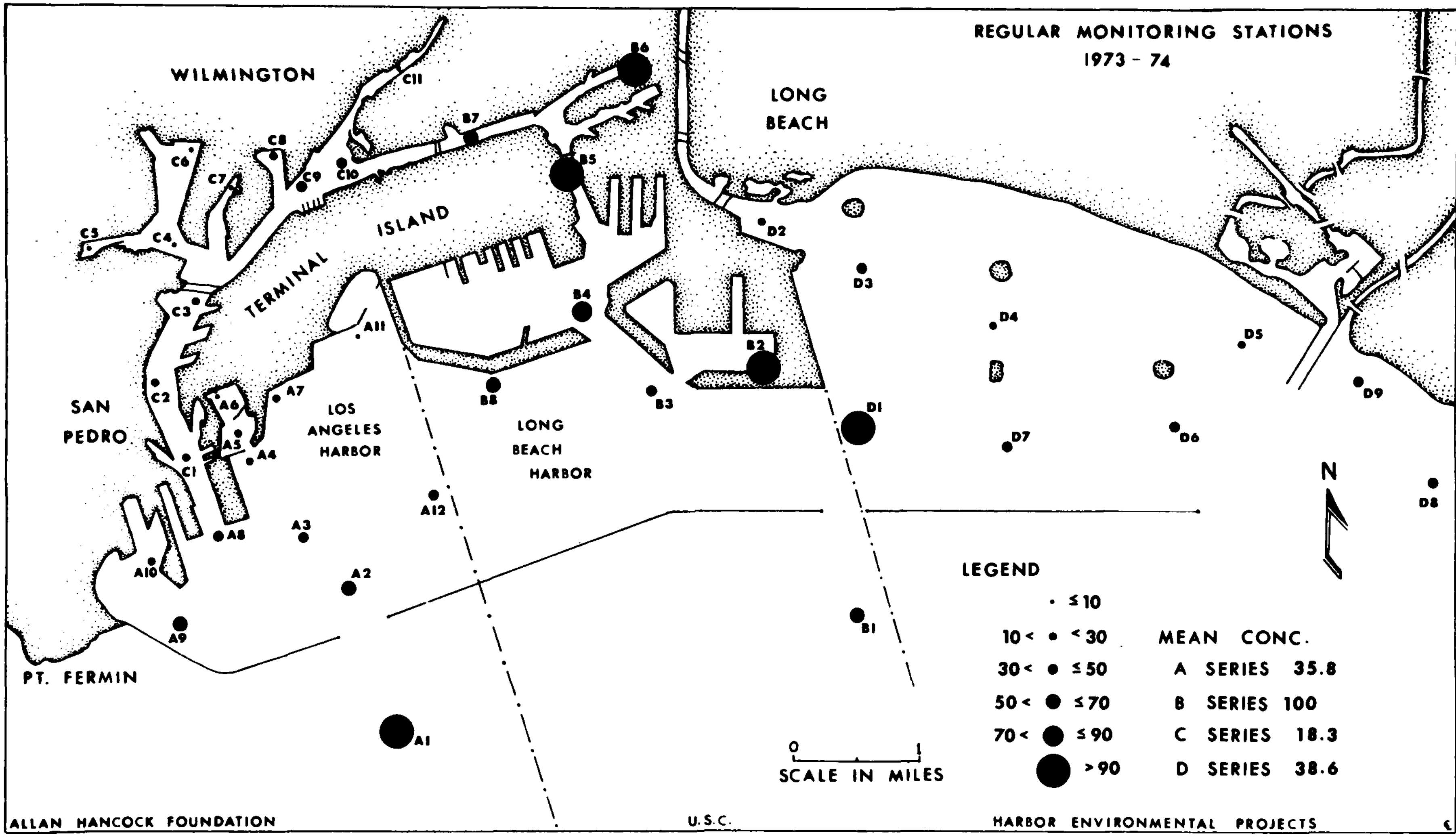
MEAN SPATIAL DISTRIBUTION OF
BARNACLE NAUPLII
Figure 4.8



MEAN SPATIAL DISTRIBUTION OF LARVACEA
Figure 4.9



MEAN SPATIAL DISTRIBUTION OF TOTAL ZOOPLANKTON
Figure 4.10



MEAN SPATIAL DISTRIBUTION OF *Corycaeus anglicus*
Figure 4.11

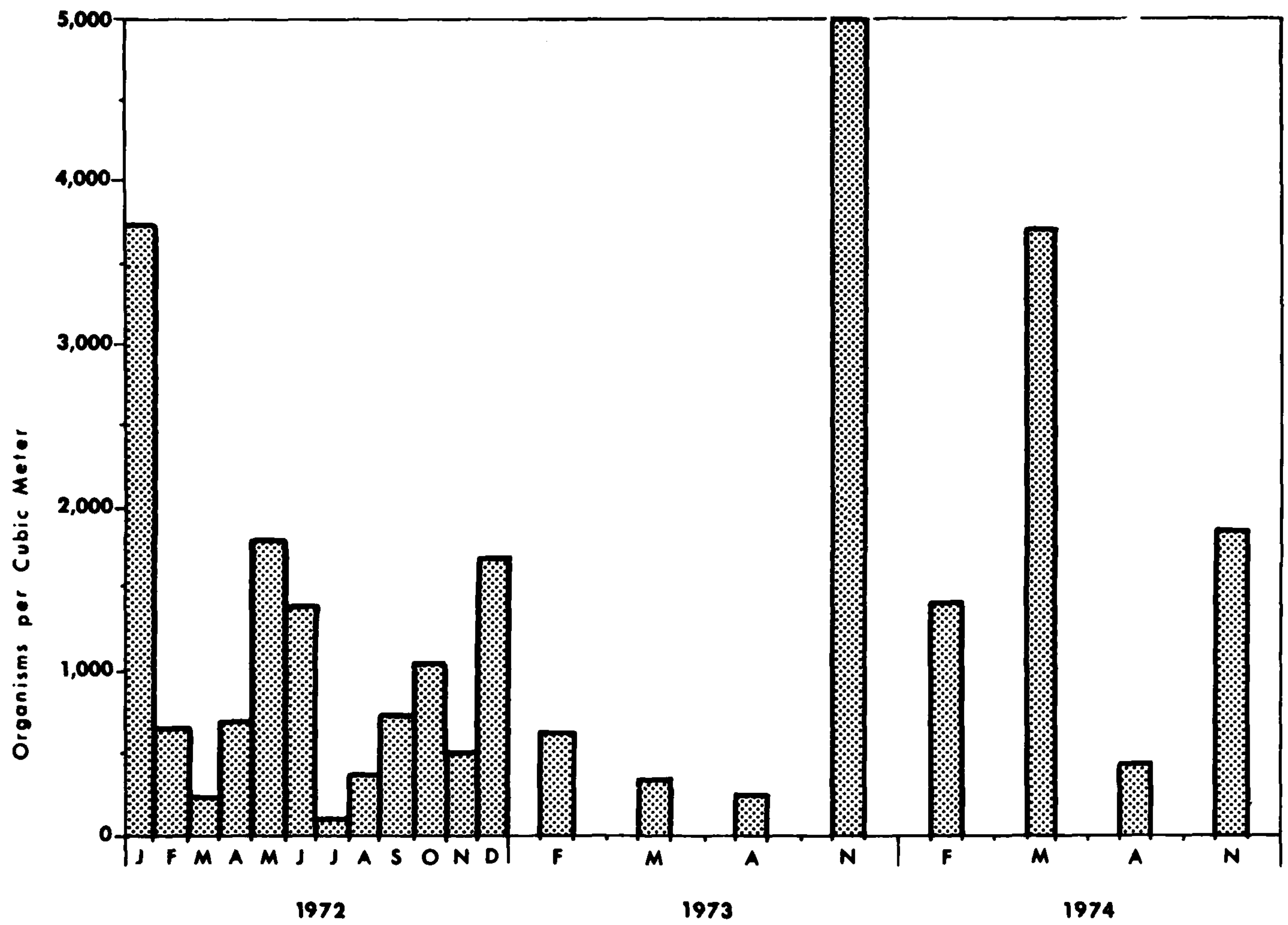


Figure 4.12. MEAN TEMPORAL ABUNDANCE OF *Acartia tonsa*

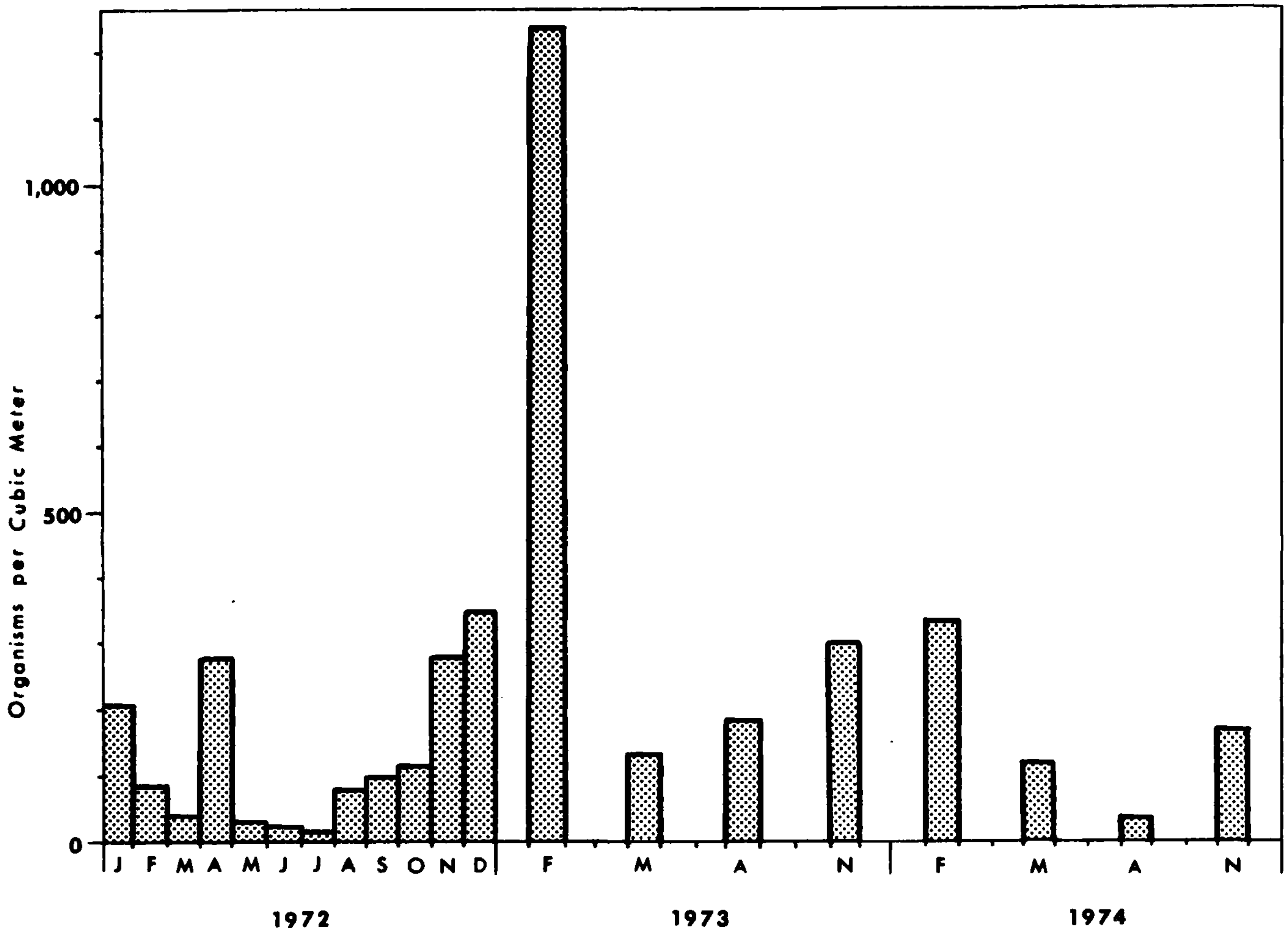


Figure 4.13. MEAN TEMPORAL ABUNDANCE OF *Paracalanus parvus*

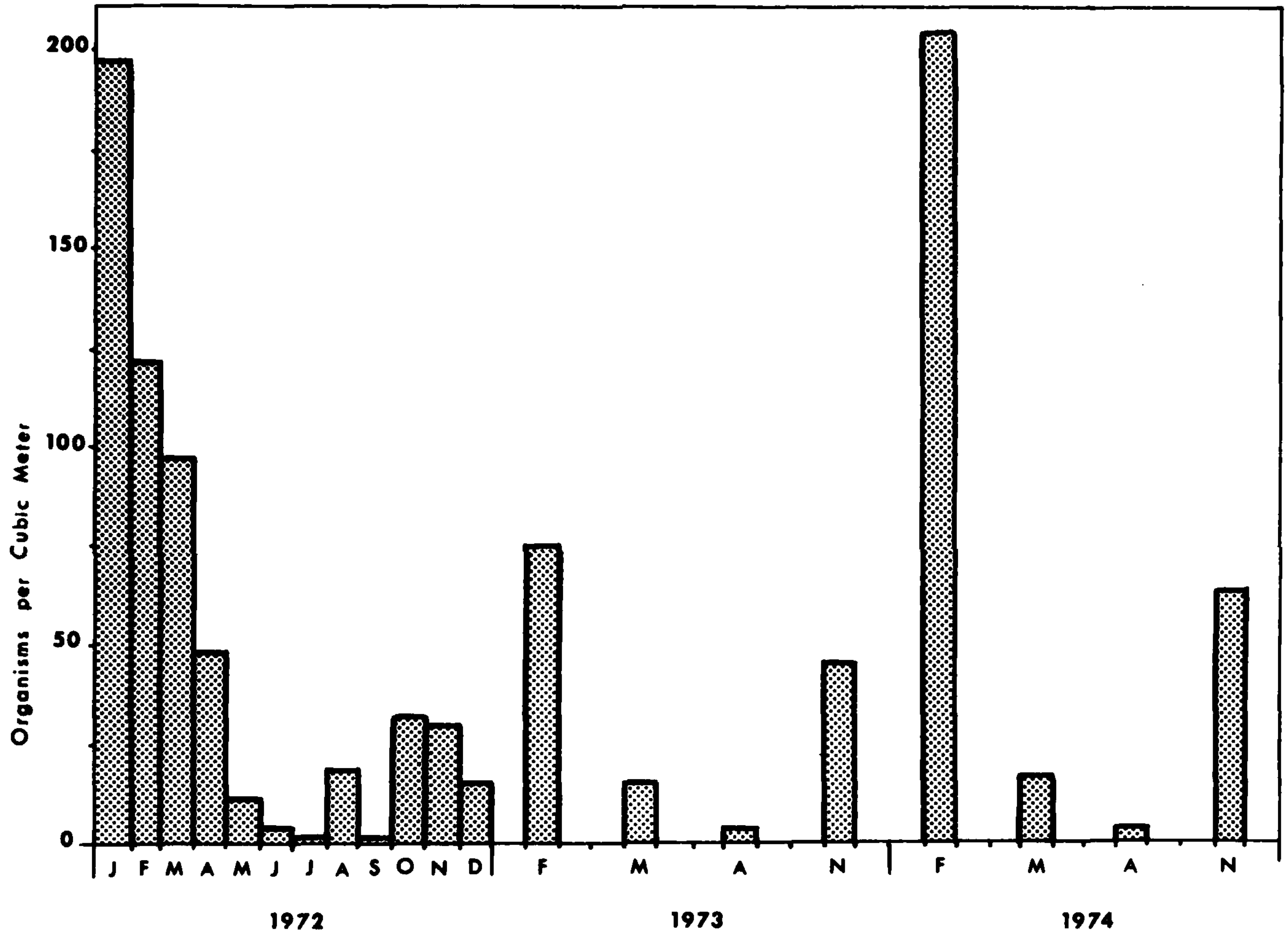


Figure 4.14. MEAN TEMPORAL ABUNDANCE OF *Corycaeus anglicus*

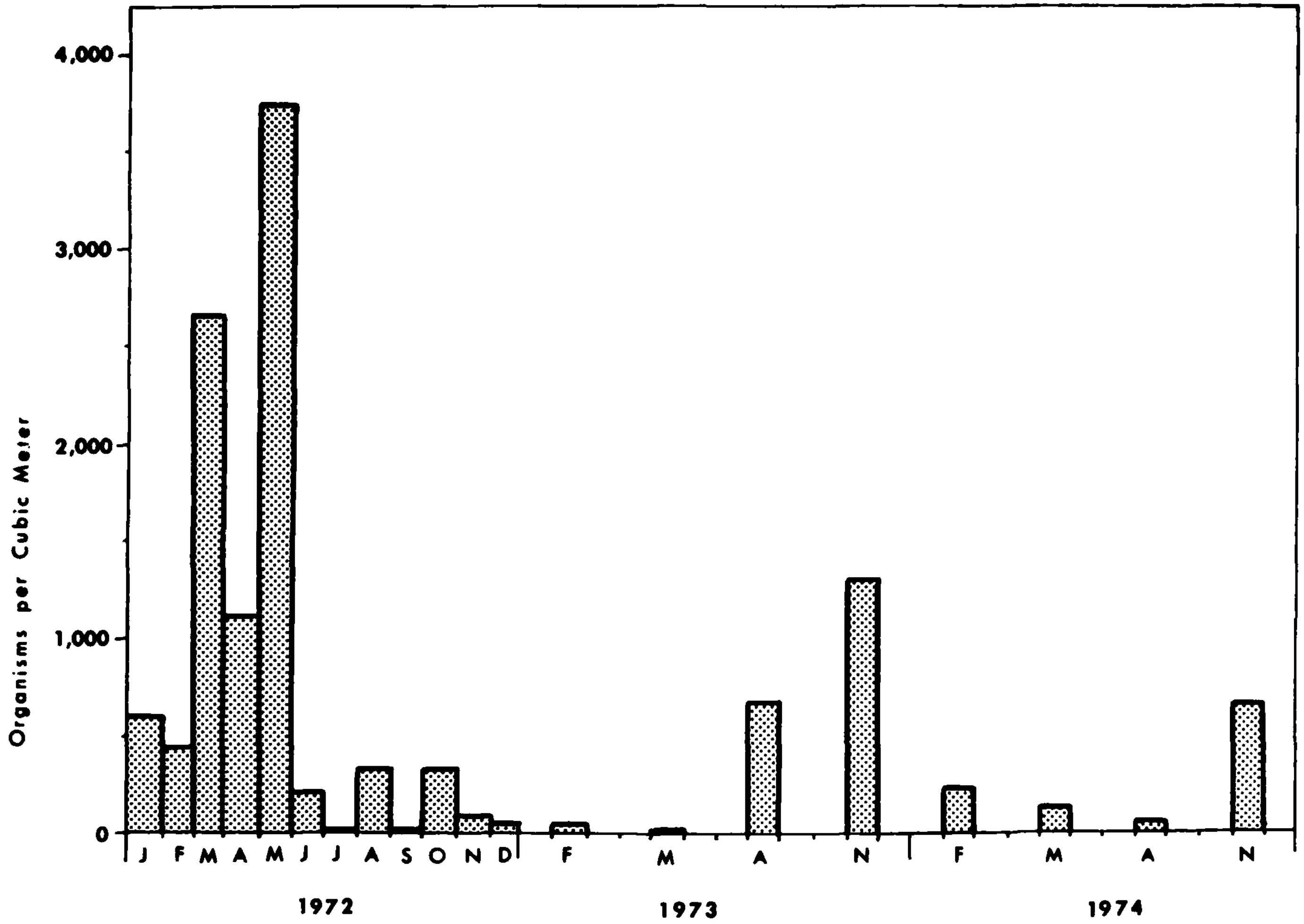


Figure 4.15. MEAN TEMPORAL ABUNDANCE OF *Podon polyphemoides*

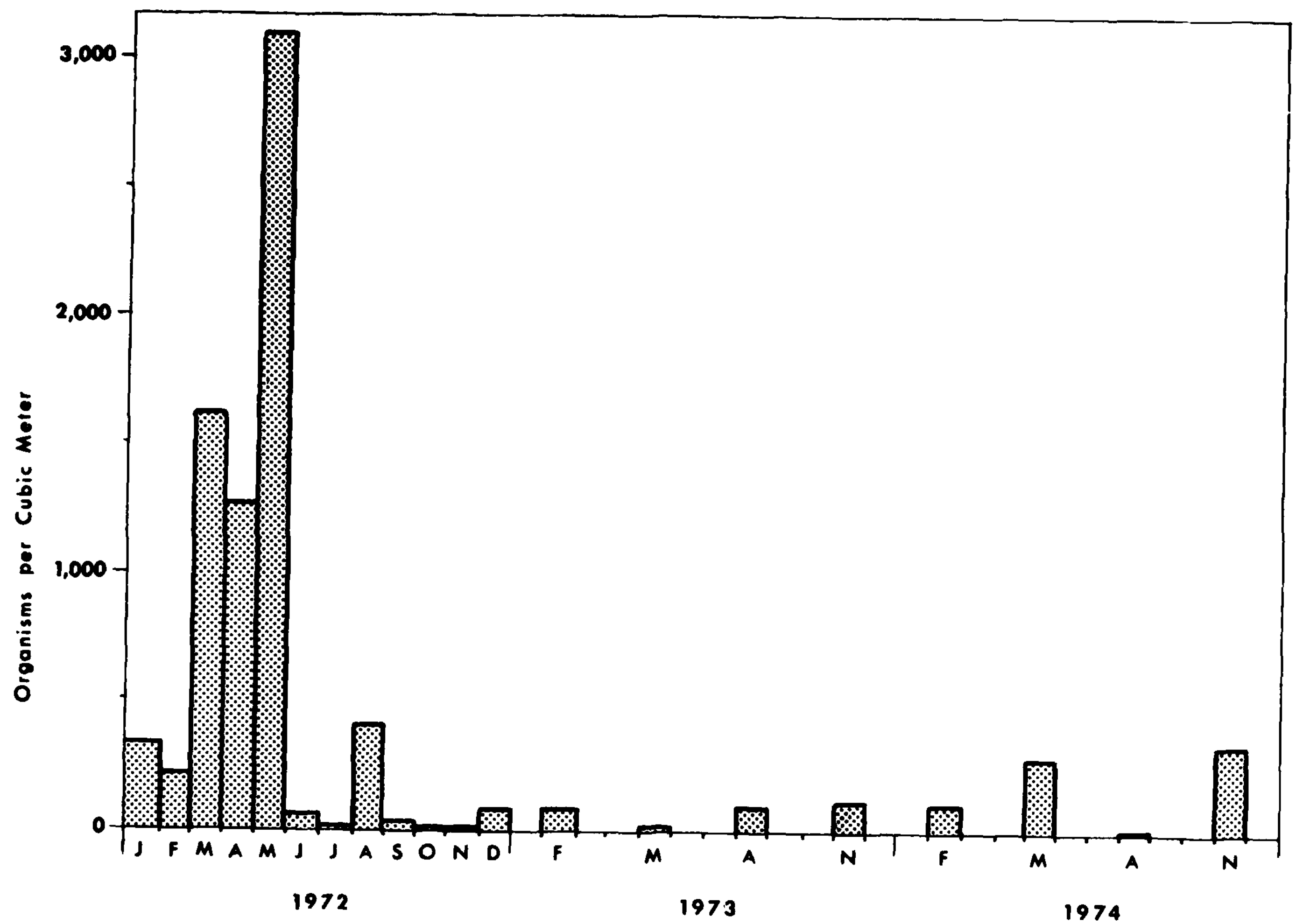


Figure 4.16. MEAN TEMPORAL ABUNDANCE OF *Evadne nordmanni*

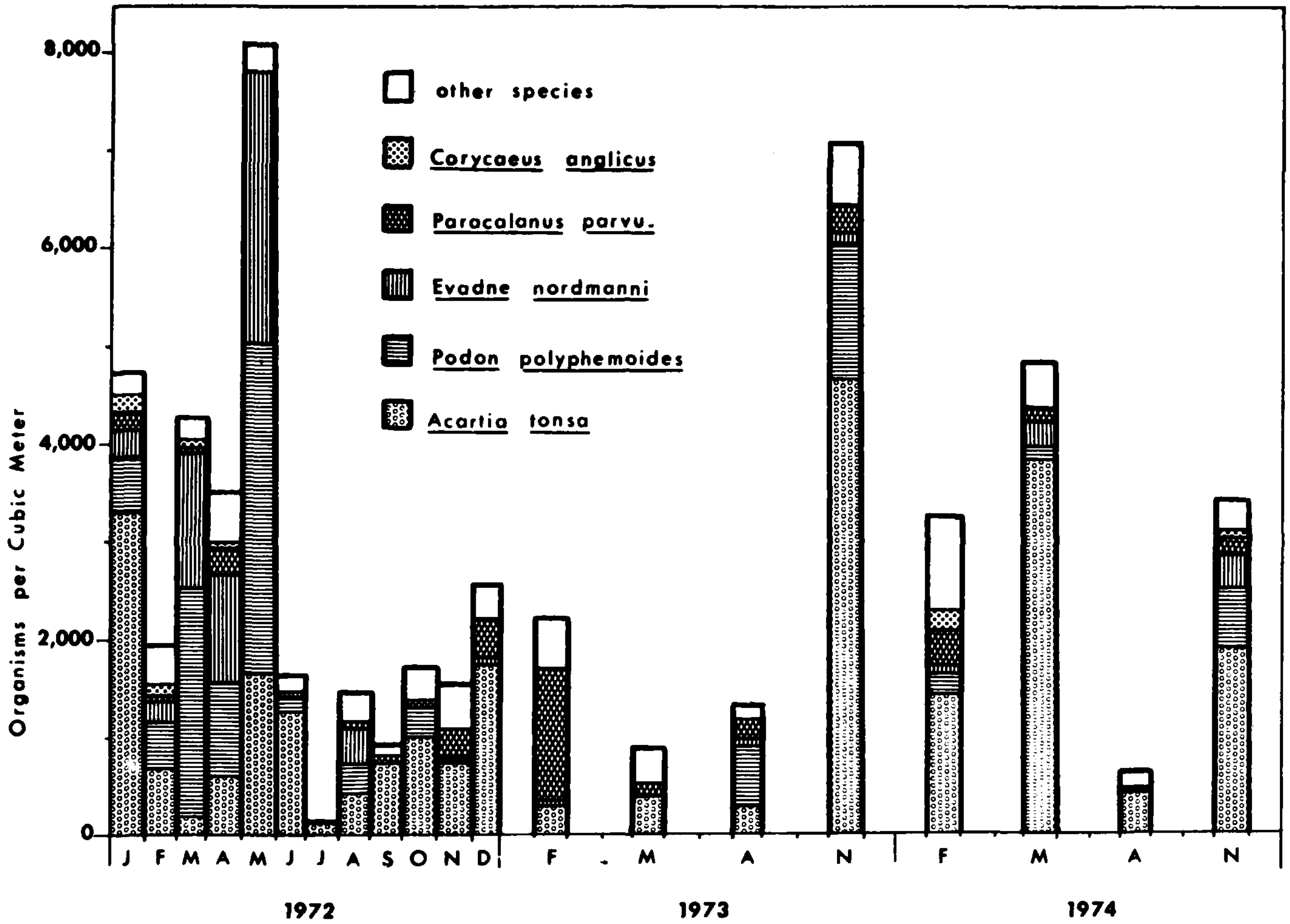
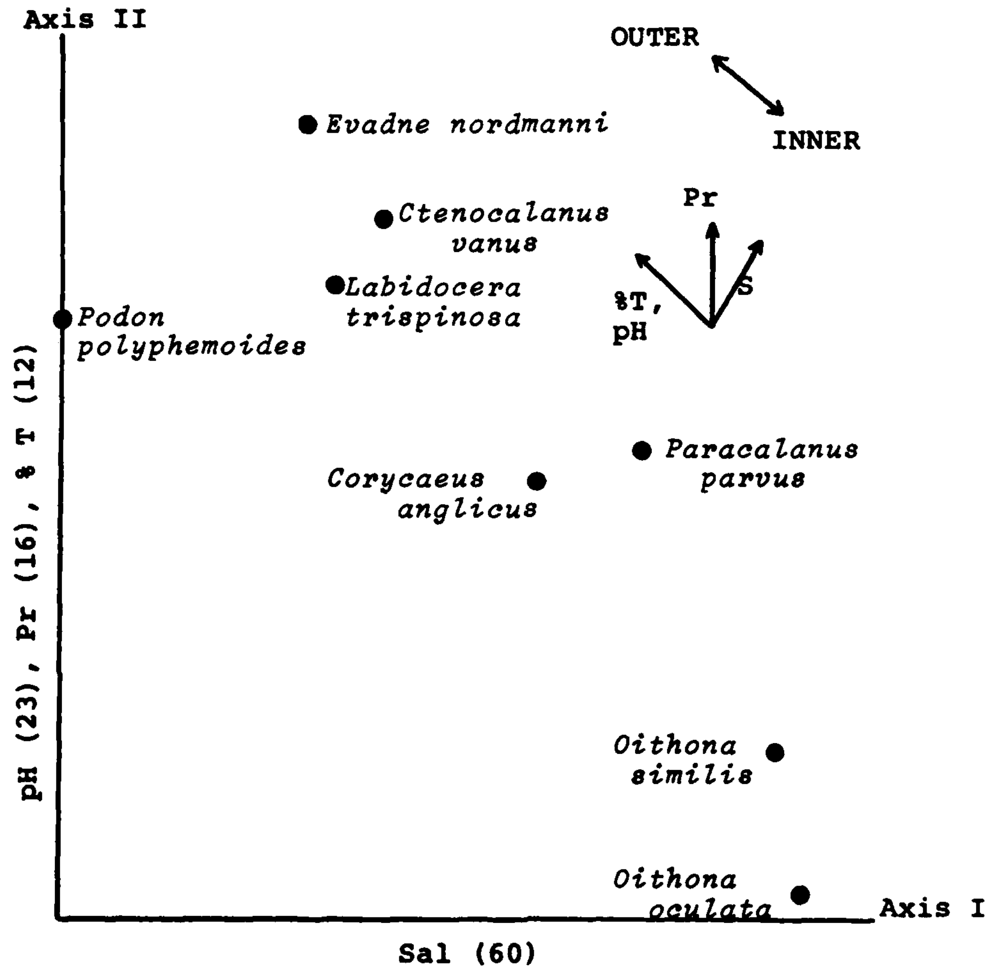


Figure 4.17. MEAN TEMPORAL ABUNDANCE OF ZOOPLANKTON AND MAJOR COMPONENT SPECIES

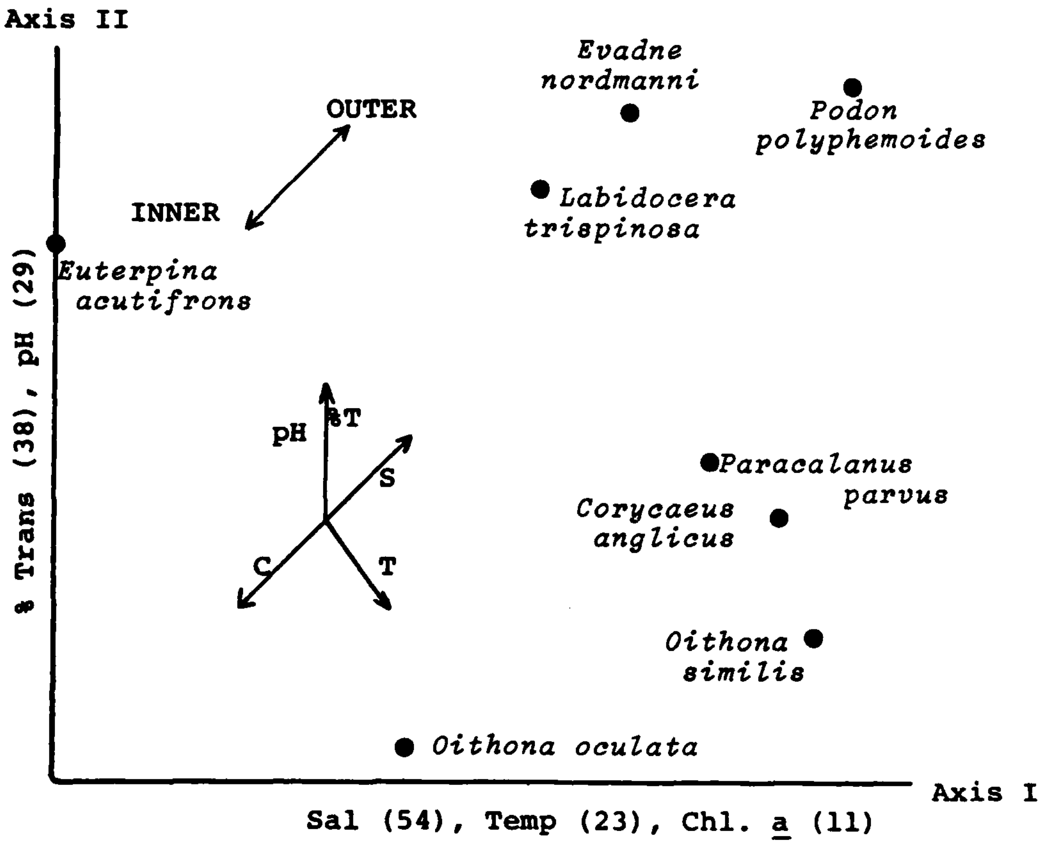


Symbols: S = salinity Pr = productivity
%T = percent transmission

Source: Data from HEP Survey taken in Feb., 1974

Figure 4.18

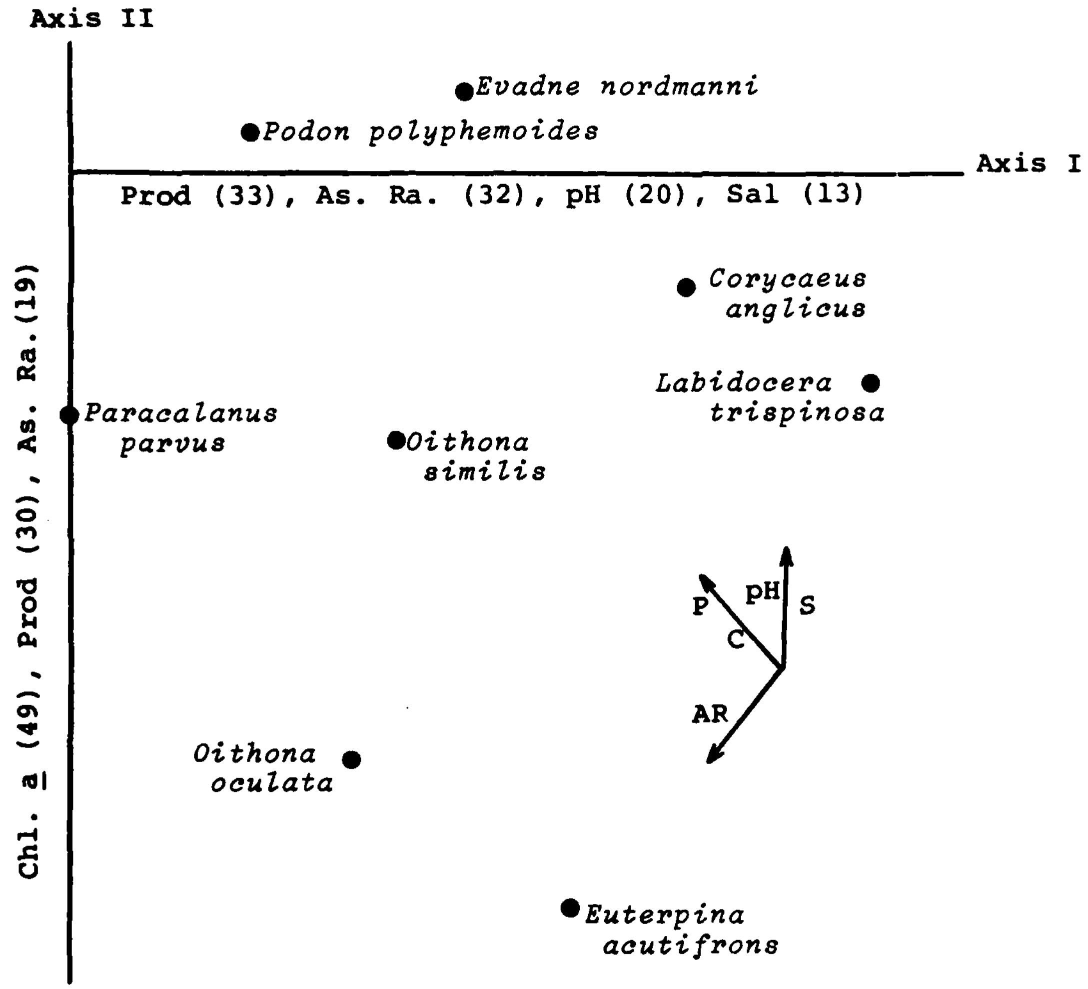
WEIGHTED DISCRIMINANT ANALYSIS OF SITE GROUPS DEFINED BY THE PRESENCE AND ABUNDANCE OF SELECTED ZOOPLANKTON SPECIES



Symbols: Pr = productivity
Chl a = chlorophyll a
% Trans = % Light Transmission

Source: Data from HEP Survey taken in May, 1974

Figure 4.19
WEIGHTED DISCRIMINANT ANALYSIS OF SITE GROUPS DEFINED BY THE PRESENCE AND ABUNDANCE OF SELECTED ZOOPLANKTON SPECIES

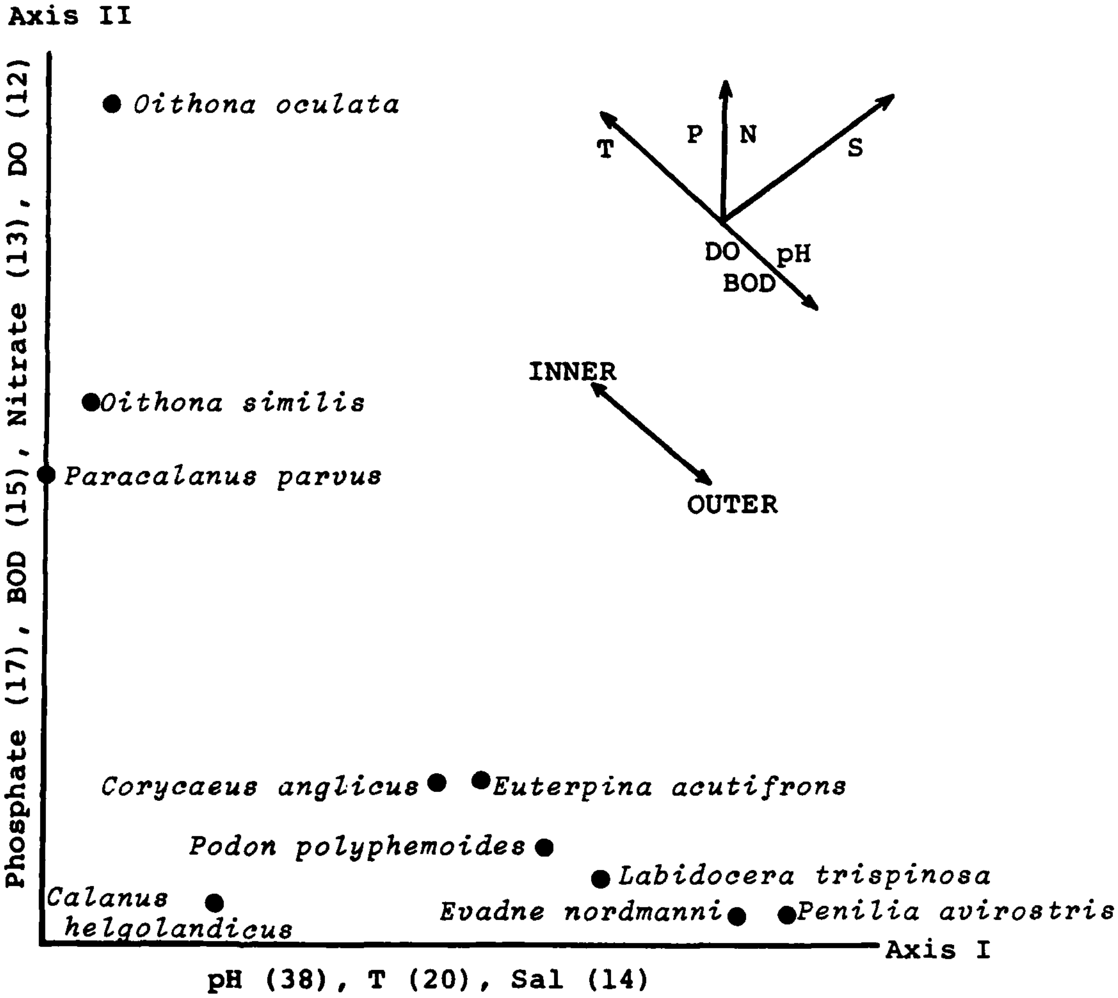


Symbols: P = productivity; S = salinity
AR = assimilation ratio
C = chlorophyll a

Source:
Allan Hancock Foundation
Data from HEP Survey taken in August, 1974

Figure 4.20

WEIGHTED DISCRIMINANT ANALYSIS OF SITE GROUPS DEFINED BY THE PRESENCE AND ABUNDANCE OF SELECTED ZOOPLANKTON SPECIES



Symbols: T = temperature; S = salinity
P = phosphate; N = nitrate
BOD = biological oxygen demand
DO = dissolved oxygen

Source: Data from HEP Survey taken in November, 1974

Figure 4.21

WEIGHTED DISCRIMINANT ANALYSIS OF SITE GROUPS DEFINED BY THE PRESENCE AND ABUNDANCE OF SELECTED ZOOPLANKTON SPECIES

Chapter 5

WATER COLUMN SETTLING/FOULING FAUNA

5.1

WATER COLUMN SETTLING/FOULING FAUNA

INTRODUCTION

The water column of harbors and other marine areas with polluted bottom sediments may have a richer fauna than standard bottom sampling techniques may indicate. Furthermore, plankton tows also may not sample the water column fauna completely, and their period of sampling time is relatively brief. For these reasons, settling racks were placed at 24 A, B and C stations throughout Los Angeles and Long Beach Harbors during 1973 and 1974.

Preliminary surveys carried out in the harbor at eight A stations in 1971 and 1972 showed that the racks retained eggs, larvae, juveniles and small adult plankters. The greater diversity of species and also of higher taxa collected by this technique indicated that it offers a means of evaluating the biological quality of the water column (Abbott *et al*., 1973). The early stages in the life cycles are generally more sensitive to stress, and thus, information from the newly colonized surfaces is particularly valuable in assessing the potential for recolonization where dredge and fill operations are anticipated.

The settling rack technique is not just a measure of the so-called "fouling" community. That term is an outgrowth of early naval studies on organisms that colonized ships' hulls, causing reduction in sailing times. "Fouling" is the marine faunal counterpart of the terrestrial term "weed", which is any plant growing where man does not wish it to grow. Fouling organisms are those species, plant or animal, which normally dwell attached to rock or other natural substrates, but due to their relatively unspecialized settling behavior, also colonize any available man-made substrate, *e.g.*, ship bottoms and harbor installations (Perkins, 1974).

Seasonal settlement of fouling species of polychaetous annelids in relation to the water temperature in Los Angeles-Long Beach harbors was summarized by Reish (1961, 1971). The effect of increased temperature on the settlement and development of fouling organisms in the laboratory was studied by Wolfson (1974). The distribution of polychaetes associated with fouling organisms at select stations in Los Angeles Harbor was summarized by Crippen and Reish (1969). The distribution of amphipod crustaceans as fouling organisms with reference to the influence of water turbidity was studied by Barnard (1958).

The settling rack technique samples the smaller elements

of the normal water column community, acts as a substrate for larval forms ready to undergo settlement, and also serves as a trap for eggs, larvae or juveniles which cannot escape from the screened racks after minimal growth. Thus, the racks retain not only the new settling community but also act as a capture device.

Until the present investigations, only the pilot study (Abbott, et al., 1973) has dealt with fouling and other settling organisms on a scale designed to assess extensively the biological quality and content of the waters of the Los Angeles-Long Beach Harbors. The present study is an outgrowth of that pilot study, in response to proposed dredge and landfill projects under consideration. Factors considered include temporal and spatial differences between sampling stations with respect to biotic and abiotic fluctuations, species composition of faunal assemblages, and of the harbor area in general, and seasonality of dominant organisms.

With these factors determined, the immediate and long-term impact of the various phases of the proposed dredge and landfill can be projected in relation to the influence of biotic and abiotic factors upon the settling organisms of Long Beach-Los Angeles Harbors.

METHODS AND MATERIALS

Field

Settling racks were prepared by the method of Soule and Soule (1971) using 8.5 x 16.5 cm wooden microscope slide boxes. The bottom panel of each box was removed, wire brads driven into each corner for support, and 6 mm holes drilled into each end of the box. A short length of rope was fastened to one end while the other end was weighted. Fifteen glass microscope slides (2.54 x 9.62 cm) were evenly spaced in the wooden notches. Plastic saran screening of 1.6 mm mesh was stapled over the bottom and top of the box. The short length of rope was then tied to a heavier polypropylene rope and the settling rack suspended from a floating buoy or pier piling three meters below the surface for a 28 day period.

Settling racks were collected and replaced monthly at each of 24 designated stations in Long Beach and Los Angeles Harbors. On collection, each rack was placed into a plastic one gallon container in a 10% formalin-seawater solution. The slides were later examined under a dissecting microscope and scraped of all organisms. After the wet weight was determined by volume displacement, the sample was rinsed with water to remove the formalin, and stored in a 70% alcohol-water solution

for further qualitative and quantitative procedures.

The samples were sorted into three size categories using Tyler Standard Sorting Screens. The largest organisms were retained on a screen with 2.79 mm mesh. The majority of the biomass of all samples was retained on the screen with 0.7 mm mesh while the smallest organisms were retained on a 0.25 mm mesh screen. This sorting strategy was employed to reduce the effort necessary for quantification of the smaller organisms. The 0.25 mm mesh screen retains a much larger number of individuals. The organisms retained on this screen were aliquoted (divided into equal portions) to speed counting and identification and later the number of individuals counted was multiplied by the aliquot portion to represent the whole of the 0.25 mm mesh sample. This procedure tends to accentuate the numerically dominant organisms and exclude some of the rare individuals, but it was felt that this step greatly reduced the identification time with very little sacrifice of accuracy. With few exceptions the taxa encountered on the 0.25 mm mesh screen were juvenile representatives of those species on the 0.7 mm mesh screen. After counting and identification to lowest taxon possible, the individual counts of each screen were totaled and entered into the computer for further statistical treatment.

The wet weights of select colonial organisms such as the hydroid, *Obelia* sp., were determined to the nearest 0.1 gram for a biomass estimate. This was considered a better indication of abundance because colonial organisms do not lend themselves to quantification.

Complete lists of all species identified at the 24 stations over the period of the investigation were entered in the USC Computer data bank. Because of the large number of species and locations involved, computer analysis was used to select the fifteen dominant species from the entire group.

<u>Temporal Analysis</u> (Seasonality)

Fifteen species of organisms were selected for temporal analysis because they dominated the settling rack fauna at all stations, both in number of occurrences and in numerical abundance. The fifteen dominant organisms represented a minimum of 85% to a maximum of 99% of the abundance of all organisms found at a particular station. The dominant settling rack organisms were analyzed in two ways. First, they were ranked by their relative total numerical abundance, and second they were ranked by their total number of occurrences.

Abundance and occurrence both were used because while

an organism may occur with great frequency at a particular station or stations, it may not be as widely distributed as would be expected because of a reduced reproductive potential which may be due to either natural or man-made conditions. Both abundance and occurrence were considered two ways. First they were considered in relation to all stations sampled in Los Angeles-Long Beach Harbors during 1973 and 1974. This overall approach was an attempt to express some general characteristics of both harbors as a unit. Next they were considered on a station by station basis relative to both harbors. This was felt to reflect the differences between stations and characterize each station.

The seasonal abundance for the 15 dominant settling rack organisms was determined from 1973 to 1974 at selected stations representative of the major site groups, as determined by spatial analysis. Correlations of select abiotic parameters with the abundance of the six most dominant species in Los Angeles-Long Beach Harbors was achieved with a cross correlation technique (Davis, 1973). This technique permitted the chain of abundance values for each successive month to be moved past the sequence chain of abiotic measurements for a particular parameter in such a manner as to compare each value of one with every value of the other and compute correlation values for each match position. There is a two-fold advantage to this technique. First, it allows a correlation when there is an exact correspondence of parameters., e.g. temperature and abundance for all samples. Next, it allows short time lags (2-3 months) between abiotic parameter peaks and peaks in abundance to be detected. The abundance of the dominant organisms was on a scale with other lower values.

Spatial Analysis (Distribution)

Settling rack data were analyzed on the basis of spatial differences, in which time and fluctuations in biotic and abiotic parameters were held constant in order to determine differences between stations or station groups. Composition of faunal assemblages within the study area, and the primary abiotic parameters correlating with assemblages were determined.

Representative stations from the A, B and C study areas (Figure 5.1) were selected on the basis of geographic location and on available data for abiotic and biotic parameters. Four separate periods were selected and analyzed: 1) summer (June, July and August), 1973; 2) summer (June, July and August), 1974; 3) winter (December, January, February), 1973; and 4) winter (December, January and February), 1974. The summer periods represent peak periods of settlement activity

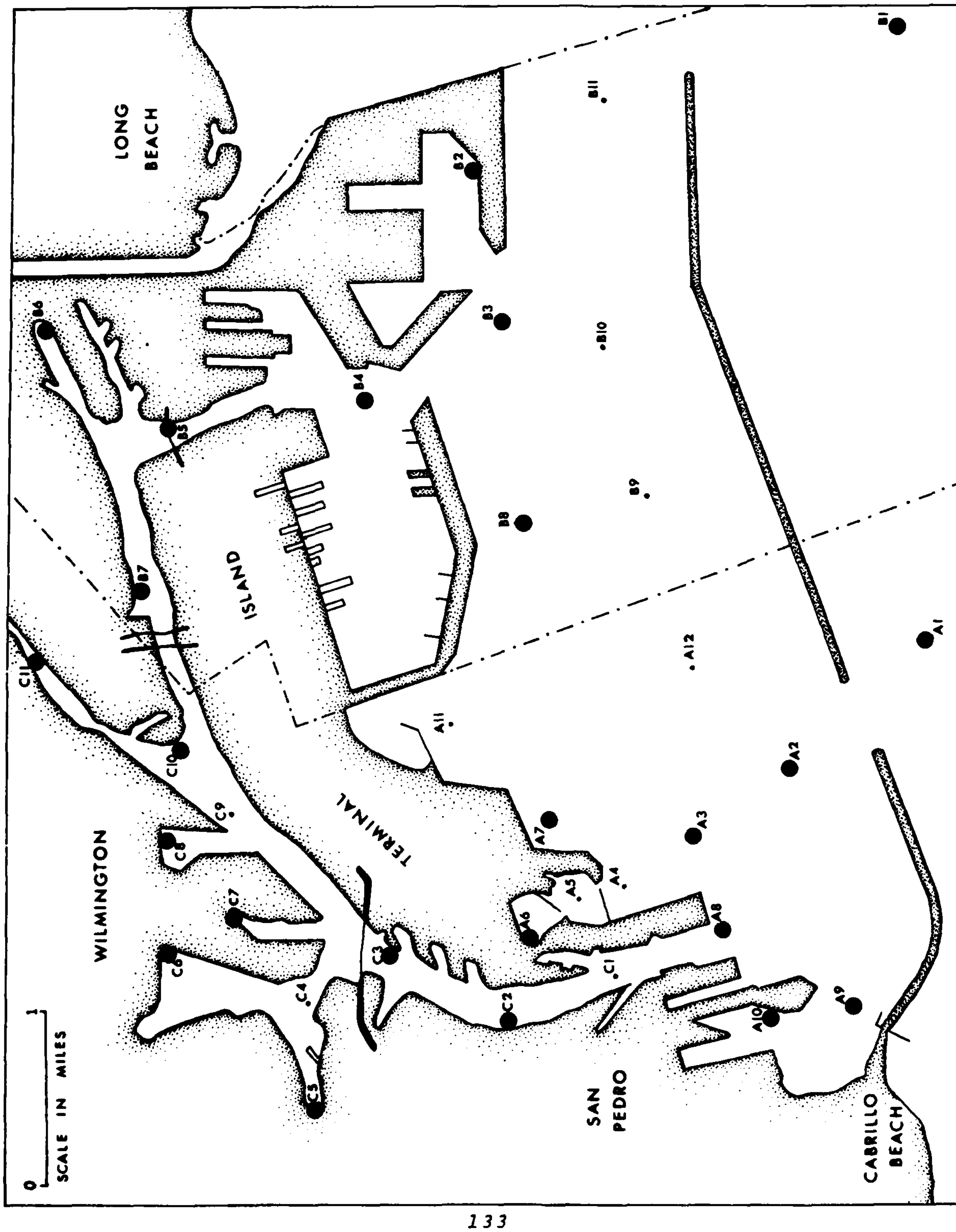


Figure 5.1. STATION LOCATIONS, MONTHLY SAMPLING

for both 1973 and 1974, while the winter periods represented minimal periods of settlement activity during both years.

Eighteen stations were analyzed in the major periods of settlement activity (summer, 1973, 1974). The same series of stations could not be followed during both winter periods due to incomplete records for some of these sites, when winter storms destroyed the settling racks. Fourteen stations were analyzed for the winter of 1973, and fifteen stations for the winter of 1974. The mean number of each species was determined for each of the four time periods.

Organisms utilized in this analysis were identified to a species level, except for a few undetermined forms that were taxonomically distinct from other related organisms and were treated as definitive species. Species were sorted on the basis of their total number within the total study area for each period, and those with fewer than two records were omitted from further analysis. The total number for each species for the time period in question was then determined at each site. Subsequent analysis of the number of occurrences included a cube root transformation and a species mean standardization and classification (see Methods, p. 2.2).

Site groups previously determined by classification were defined in respect to a series of abiotic parameters corresponding to the biotic data for each three month period, but the abiotic data also included the previous month. Thus, the biotic period of June, July and August would also include the abiotic data recorded for May. Abiotic measurements were made in the field at approximately monthly intervals at each site; thus six to eight measurements were averaged for each abiotic parameter.

The abiotic parameters used in this analysis included temperature minimum, temperature range, salinity minimum, salinity range, dissolved oxygen minimum, dissolved oxygen mean, turbidity mean, and biochemical oxygen demand mean. Two additional parameters were included which represent a measure of the available food for planktotrophic larvae prior to settlement. These parameters included chlorophyll *a*, as determined by ^{14}C uptake, and assimilation efficiency based on a ratio of total carbon and chlorophyll *a*.

Variables which were distinctly skewed were log transformed. An arc sine transformation was applied to turbidity measurements which are recorded as percent transmittance. Multiple discriminate analysis was used to determine which

of the measured abiotic variables correlate with the pattern from the site classification.

Species groups were determined from a classification based on the relative abundance of each species at each station. Species groups were then compared to their occurrence in the station groups by means of a two-way table. Extrapolation of the abiotic parameters affecting the respective species groups were included in terms of an environmental stress gradient.

RESULTS

Temporal Analysis: Abundance

The amphipod *Jassa falcata* was the most numerically abundant animal overall on settling racks within both harbors. It was numerically dominant at 11 of 24 stations sampled. *Ciona intestinalis* was next, ranking first at five stations. *Corophium* ranked third with dominance at 3 stations, and *Hydroides pacificus* was dominant at only two stations. *Mytilus edulis*, the bay mussel, and the polychaete *Polydora limnicola* were dominant at a single station only. Other species which ranked second or third were somewhat mixed, but consisted primarily of *Corophium acherusicum, Ciona intestinalis* and *Hydroides pacificus*.

The overall harbor abundance of *Jassa falcata* was 42 percent greater than that of the second ranked amphipod *Corophium acherusicum*. This may have been due to an overall greater reproductive potential at the stations occupied or to a greater or more frequent brood. The tunicate *Ciona intestinalis* was third ranked in abundance and frequency occurrence.

A station by station summary of the 15 dominant species of animals is compiled in Table 5.2. The species were grouped by taxa. The fraction associated with each species is the rank of the species by abundance over the rank of the individual by occurrence. At the end of each column of species are the total number of animals identified to the species taxon for that station for a two year period and the percentage of the total species numbers which the 15 numerically dominant species represent. Species which occurred only a few times, but in large numbers when there,were eliminated to reduce the overall effect of averaging the total numbers of individuals.

The species composition of the 15 dominant organisms for all stations sampled in Los Angeles and Long Beach Harbors was determined. These groups were found to be composed of six arthropods, six annelids, one tunicate, one mollusc and

one tanaid.

The arthropod group was composed of four gammaridean amphipods: *Corophium ascherusicum, Jassa falcata, Podocerus brasiliensis* and *Stenothoe valida*, and two caprellid amphipods: *Caprella californica* and *Caprella equilibra*.

The annelid fauna consisted of the polychaetes *Armandia bioculata, Capitella capitata, Ctenodrilus serratus, Hydroides pacificus, Platynereis bicanaliculata* and *Polydora limnicola*.

The last three groups of animals were the tunicate, *Ciona intestinalis;* the tanaid *Anatanais normani*, and the mollusc *Mytilus edulis*.

Occurrence

The number of occurrences of the most dominant 15 species within Los Angeles-Long Beach Harbors during the 1973-74 sampling period was an important factor relating specific animals and their distribution. The number of occurrences at a given site is a better indication of distribution than the individual abundance, but fails to indicate the degree of reproductive potential achieved in response to the surrounding physical, chemical, and biological parameters. Table 5.1 shows the number of occurrences and the total number of individuals of the 15 dominant organisms found in Los Angeles-Long Beach Harbors during the 1973-74 period.

The most frequently occurring organisms within both harbors was the amphipod *Corophium acherusicum* which dominated occurrence at 13 of the 24 stations. *Jassa falcata*, another amphipod, was next with the largest number of occurrences at five stations, followed by the tunicate *Ciona intestinalis*, the amphipod *Caprella californica* and the tanaid *Anatanais normani*, with dominant occurrences at 3,2, and 1 stations, respectively.

The three most frequently occurring species were also found to be similar in number of occurrences: *Jassa* and *Corophium* differed only by 8 percent, while *Ciona* differed 17 percent from the top ranked *Corophium*.

As indicated in Table 5.2, occurrences as well as abundances were dominated by a total of 35 species from which the most abundant species were found at all stations. These data demonstrate that generally the stations are alike in that a few individuals are common to many stations or ubiquitous. Aside from the ubiquitous individuals, the species composition varies considerably from station to station throughout the harbors.

TABLE 5.1 Rank of the 15 Dominant Species Found in Los Angeles-Long Beach Harbors According to Total Number of Occurrences and Numerical Abundance over 1973 and 1974

Rank	Total Occurrences		Total Individuals	
	Name	Number	Name	
1	*Corophium acherusicum*	654	*Jassa falcata*	625,900
2	*Jassa falcata*	597	*Corophium acherusicum*	266,102
3	*Ciona intestinalis*	547	*Ciona intestinalis*	185,439
4	*Polydora limnicola*	475	*Hydroides pacificus*	82,347
5	*Platynereis bicanaliculata*	458	*Polydora limicola*	68,536
6	*Podocerus brasiliensis*	440	*Podocerus brasiliensis*	47,516
7	*Caprella californica*	382	*Caprella equilibra*	29,260
8	*Stenothoe valida*	379	*Mytilus edulis*	28,131
9	*Caprella equilibra*	378	*Stenothoe valida*	17,650
10	*Anatanais normani*	374	*Ctenodrilus serratus*	17,390
11	*Armandia bioculata*	368	*Caprella californica*	16,848
12	*Hydroides pacificus*	353	*Armandia bioculata*	15,011
13	*Capitella capitata*	341	*Anatanais normani*	9,516
14	*Mytilus edulis*	332	*Capitella capitata*	8,119
15	*Ctenodrilus serratus*	319	*Platynereis bicanaliculata*	6,055

Table 5.2. SUMMARY OF RANK BY ABUNDANCE/RANK BY OCCURRENCE OF DOMINANT SETTLING RACK ORGANISMS IN LOS ANGELES-LONG BEACH HARBORS AT ALL STATIONS DURING 1973-74 SURVEY.

	A1	A2	A3	A6	A7	A8	A9	A10	B1	B2	B3	B4	B5	B6	B7	B8	C2	C3	C5	C6	C7	C8	C10	C11
ANNELIDA																								
Polychaeta																								
Armandia bioculata		8/8	12/12	10/6	9/9	4/9	8/4	7/7	14/15	15/14	14/14	11/12		15/24	11/9		11/3							
Autolytus sp.						11/24																		
Capitella capitata				5/4	14/14		13/21			14/16			13/8	5/2	12/7				11/3	9/5	6/4	12/5		8/3
Ctenodrilus serratus		10/15		9/7				10/17		7/18			4/4	4/4	15/19	15/12	10/14	6/6	6/11	5/7	7/6	8/14	14/18	12/17
Eumida sanguinea																				15/23				
Halosydna brevisetosa	6/14			13/10	13/8		15/12				12/17								9/17					15/19
Hydroides pacificus		12/16	13/17	6/11		7/12	10/15	9/14		5/11	2/18		2/14	2/7	1/14	13/18	4/10	4/9	1/4	6/8	4/3	3/3	4/10	3/5
Ophiodromus pugettensis				12/14										14/15						11/10				
Paleanotus bellis	9/8	13/13	11/14	15/18	5/19				9/8		13/12	9/11		11/6			13/16				13/12			13/11
Platynereis bicanaliculata	13/4	14/3	10/4		12/3		12/9	14/8	11/6			15/7	9/12	12/9							14/9	15/13		
Polydora ligni				4/19														10/20	7/14	10/36	5/13	13/16	15/21	4/9
Polydora limicola	10/9	11/4	9/5	1/3	8/4	9/10	9/8	5/16	8/10	11/6			12/6		14/10		8/8	7/5	4/9	4/4	3/10	4/6	13/8	5/4
Polyopthalmus pictus	15/13	15/18	15/16		6/12	14/26	14/14	12/15	12/12		5/16	4/17												
Schistomeringos longicornis														7/11				13/26	8/10	13/21	10/10	14/12		14/14
ARTHROPODA																								
Amphipoda																								
Caprella californica	12/11		7/11				5/6	8/9		9/5		5/1	7/5	9/12	5/1	12/6	14/13	14/14		14/16		11/11		
Caprella equilibra	3/3	4/11	5/9	14/8	11/15	12/15	11/11	13/13	4/4	12/9	4/4	6/4	10/11	13/18			7/9		14/16				7/9	
Caprella gracilor	14/26																							
Caprella irregularis									5/10															
Caprella verrucosa		9/5			15/16	8/8					10/13					10/11								
Corophium acherusicum	2/2	2/2	2/2	2/1	2/1	3/2	3/1	3/1	2/2	6/2	6/1	3/2	3/1	1/1	4/3	2/1	1/1	2/1	2/2	2/1	1/2	2/2	3/1	2/1
Deutella californica						13/22																		
Elasmopus rapax								15/15		13/7					7/6	14/9			10/7	8/6	11/7	10/8	8/7	
Eurystheus thompsoni											15/10					8/7							10/32	
Ischyrocerus litotes																4/22	9/32							
Jassa falcata	1/1	1/1	1/1	8/2	1/2	1/4	1/2	2/2	1/1	1/1	1/2	1/3	1/2	7/5	3/4	3/3	3/4	3/4	13/12	3/3	15/16	7/4	2/4	11/6
Photis bifurcata										3/12		7/14	14/16	10/16	6/15	9/10	12/17	15/16				5/9	5/14	
Podocerus brasiliensis	4/5	6/6	6/3	11/16	4/7	5/5	4/3	6/4	7/5	2/4	3/3	8/5	6/13			1/4	6/7	8/11		12/12			11/12	
Stenothoe valida	5/10	7/7	8/6		10/11	6/6	6/7	11/18	3/3		7/6	12/[illegible]	8/15		9/11	5/5	15/11			7/15				
Cirripedia																								
Balanus sp.																		11/27					12/29	6/25
Balanus amphitrite				7/9											13/22		5/19	5/22	5/20		9/14	6/10	6/17	9/22
Isopoda																								
Limnoria tripunctata															10/8			9/2	12/5		8/5			10/8
Tanaidicea																								
Anatanais normani						15/1			15/7	9/10	11/7		11/7	6/10	8/5	11/8		12/12	15/8		12/11	9/7	9/5	7/7
MOLLUSCA																								
Pelecypoda																								
Hiatella arctica	8/18		14/21						6/30			14/27												
Mytilus edulis	7/7	5/12	3/10	3/5	10/14		7/13	1/12	10/9	10/15	9/8	10/13	15/21			6/13								
TUNICATA																								
Ciona intestinalis	11/6	3/9	4/7	3/5	7/6	2/3	2/5	4/3	13/13	4/3	8/11	2/6	5/3	2/3	2/2	7/2	2/2	1/3	3/1	1/2	2/1	1/1	1/2	1/2
NUMBER OF MONOSPECIFIC SPECIES	37	47	47	46	50	46	54	64	27	46	45	41	50	47	49	50	47	49	37	58	45	32	38	29
PERCENT REPRESENTATION BY 15 MOST ABUNDANT SPECIES	99	92	98	92	95	94	95	93	86	91	90	90	98	97	93	86	90	90	99	95	97	98	97	99

Diversity

The number of species of Polychaeta, Amphipoda and Mollusca present on settling racks at each station in Los Angeles-Long Beach Harbors is presented in Table 5.3. There was a mean number of 21 polychaete species present at all stations and the average number of species of polychaetes for each group of stations was very close to the overall mean. The lowest number of species at the A and B groups occurred at A1 and B1, stations outside the breakwater. The maximum number of species occurred at A10, C6 and C3.

The mean number of amphipods was 11.7. In general, there was a slight reduction of species mean from the outer harbor stations to the main channel stations, and a further reduction from the main channel stations to inner harbor slip stations. There appears to be no particular pattern for each station. The mean number of molluscs was 4.9. The mean species value for the outer harbor site group was above the overall mean, while channel and inner slip means were lower. There is a general trend of reduced species numbers as the stations progress from outer harbor to inner harbor stations, with some exceptions. This pattern is also generally reflected in the other species means representative of the few remaining groups.

The number of species present at each individual station should not be construed as an actual representation of the species diversity at that station. Species diversity changes with time and cannot be adequately determined for a period of two years. The fluctuation of species composition within the two year period at each station may be extreme. The settled species at a station may be wiped out by fluctuations of the physical, chemical or biological parameters and resettled by different species which may tolerate these new parameters over an extended period of time which includes several seasons.

Biomass

The biomass for each settling rack was determined, but the biomass of individual species of settling rack fauna was not, because the majority of organisms encountered were of a microscopic size. Even large numbers of these did not appreciably account for a large portion of the total biomass at each station. This was especially so at stations where large amounts of the hydroid *Obelia* sp. or large numbers of the tunicate *Ciona intestinalis* occur. Where these two organisms occurred frequently, the biomass was dominated by each respective organism. In each sample where there was a proportionately large wet weight, the biomass was dominated

TABLE 5.3. Numbers of Species on Settling Racks by Station Groups

Station		Polychaetes	Amphipods	Molluscs	Other	Total
Sea	A1	16	12	4	5	37
Buoy	B1	15	13	5	4	27
Mean		15.5	12.5	4.5	4.5	32
Outer	A2	20	16	4	7	47
Harbor	A3	23	13	5	6	47
	A8	20	11	5	10	46
	A9	24	13	8	9	54
	A10	30	14	8	12	64
	B8	17	16	10	7	50
Mean		22.3	13.8	6.6	8.5	51.3
Outer	A6	22	12	5	7	46
(stressed)	A7	22	12	7	9	50
Mean		22	12	6	8	48
Channel	B2	22	11	3	10	46
	B3	19	13	5	8	45
	B4	18	12	3	8	41
	B5	25	11	5	9	50
	C2	21	11	6	9	47
	C3	30	9	4	6	49
	C10	17	12	3	6	38
Mean		21.7	11.28	4.14	8	45
Inner	B6	24	8	5	10	47
Slips	B7	20	13	7	9	49
	C5	17	11	2	7	37
	C6	29	12	6	11	58
	C7	24	9	4	8	45
	C8	15	9	2	6	32
	C11	14	7	2	6	29
Mean		20.4	9.8	4	8.14	42.42
Mean of all stations		21.0	11.7	4.9	8.2	45.0

primarily by two organisms. In nearly every instance the hydroid *Obelia* sp. and the tunicate *Ciona intestinalis* accounted for most of the appreciable wet weight.

The bryozoans, *Bugula californica* and *Bugula neritina* occasionally accounted for the majority of the biomass. *Bugula californica* was sporadically present at many stations throughout the harbor at varying times of each year, but only accounted for substantial portions of the wet weight from August to October of each year, and always at terminal channels of the stations A7, B6, C5 and C8. *Bugula neritina* also had low wet weight occurrences at many stations and times throughout the years. The seasonal increases in production also occurred from August to October, but, unlike *B. californica*, only at outer harbor stations such as A3, A7, A9 and A10.

The hydroid *Obelia* sp. accounted for large portions of the biomass wet weight at outer harbor stations such as A1, A2, A3, B1, B3 and B4. There were a few sporadic *Obelia* blooms outbreaks at stations C2 and C3, but these were trivial compared with production at stations further in the outer harbor. The peak production period for *Obelia* sp. was from June to November. Abundance was low from December to March. Generally there was a gradient of decreased production as each station was located further within the harbor interior.

The tunicate, *Ciona intestinalis*, was found at all stations at varying times, but the peak abundances were during June to November, predominantly at the C stations such as C2, C3, C6, C8, C10 and C11. At these stations it comprised the majority of the biomass wet weight. The abundance of *Ciona* decreased from the inner harbor stations to the outer harbor areas. At the outermost stations, the hydroid *Obelia* supplanted and surpassed *Ciona* in biomass wet weight.

Seasonal Abundance

Most of the dominant species had their seasonal peak abundance restricted to the summer-fall season of each year. Generally there was a period of increased abundance which began approximately in June and usually extended to July. This was followed by a period of increased settlement from late July to October. There was a general decline during late November and December and abundance remained low until March. In Figures 5.2 and 5.3, abundances are plotted according to the square roots of the mean numbers.

Mytilus edulis had two peaks of increased settlement activity. The first peak was from March to June, followed by a one-month period of reduced abundance, after which a second period of abundance occurred from August to September.

This semiannual seasonal abundance is also found in the polychates *Armandia bioculata* and *Platynereis bicanaliculata*. *Armandia* had primary seasonal peak abundances in March, April and June, 1973 and a secondary period from September to November. In 1974, peaks occurred in February, May-July, and September-November. While *Platynereis* had the same peak primary period as *Armandia*, the secondary period was somewhat more abbreviated and restricted to July and August.

One species of polychaete, *Ctenodrilus serratus*, had a shortened seasonal abundance period which extended from May to September. The polychaete, *Polydora limnicola*, had an extended settlement period from February to November. While *Polydora* showed almost no periodicity, the polychaete *Capitella capitata* was the only polychaete to show a completely acyclic seasonal abundance.

The seasonal settlement of species representative of the stress groups of species, at the station site groups defined on p. 5.17- 5.18 are presented in Figures 5.2 and 5.3. The graph of the ubiquitous stress group represented by *Hydroides pacificus* shows a marked seasonal trend which corresponds with the summer and fall months. The polychaete *Armandia bioculata*, which represents the high stress group, shows a semiannual peak abundance during the spring and fall periods. The amphipod, *Stenothoe valida*, representing the ubiquitous low stress group shows a late summer-fall peak.

Abiotic Correlations

Cross correlations of abundance with the abiotic factors of temperature, salinity, dissolved oxygen, biological oxygen demand, turbidity, and wet weight of the six most dominant species at stations A2, A6, B1, B5, B7, C2 and C3 showed high correlations with temperature (Table 5.4). Correlations with the other abiotic parameters showed occasional significant values but failed to denote the strong trend demonstrated with temperature.

The amphipods *Jassa falcata* and *Corophium acherusicum*, and the polychaete *Hydroides pacificus* were very significantly correlated (P=0.01) at nearly all stations. Two exceptions were found. *Hydroides pacificus* did not correlate with temperature at station B1, due to the reduced abundance outside the harbor where temperatures were reduced. A correlation was found in *Ciona intestinalis* at stations B1, B5, B7 with a time period 2-3 months before peak abundance, which may be a lag between initiation of reproduction and variations in temperature until abundance is reached.

Two species of polychaetes, *Capitella capitata* and

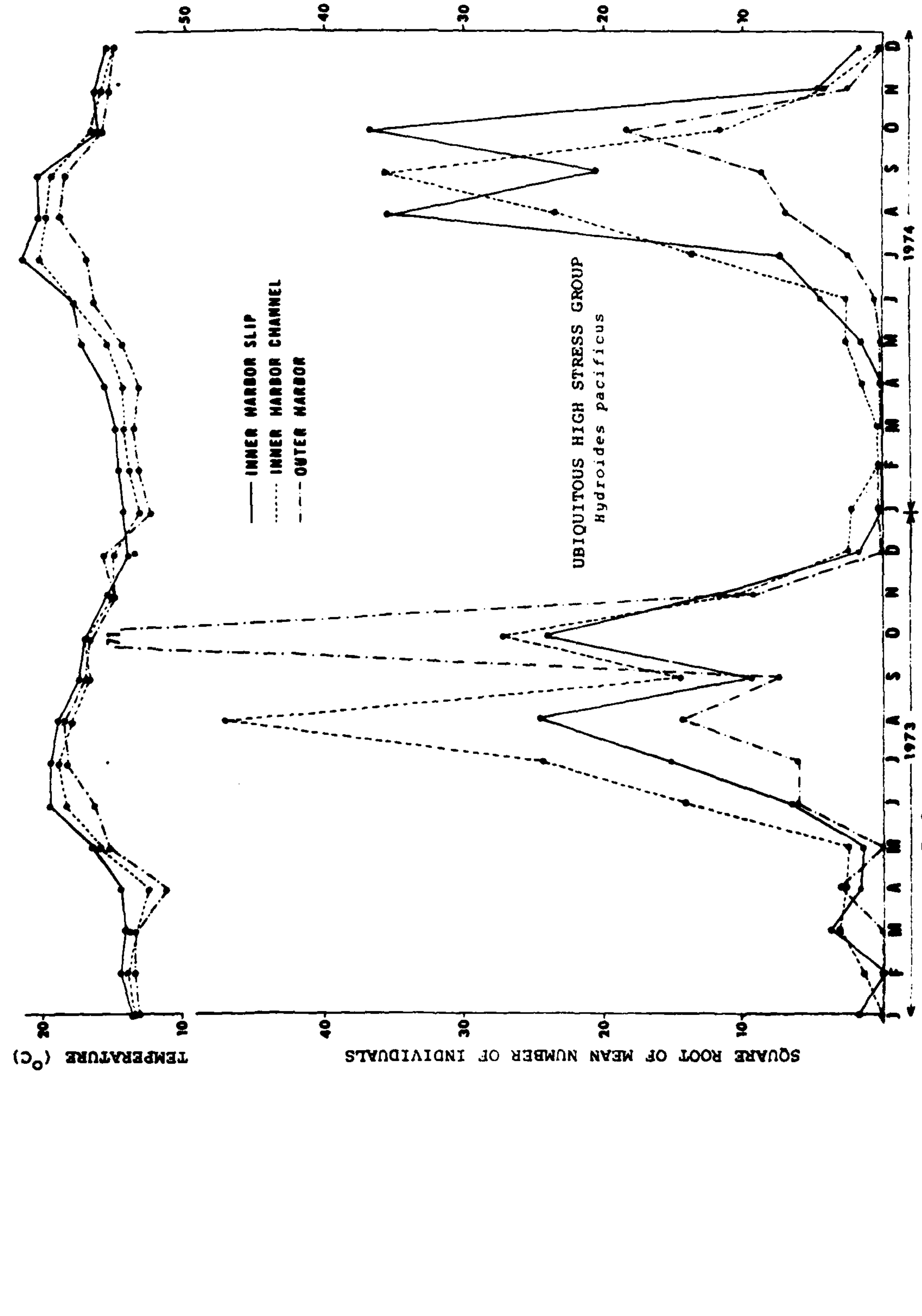


Figure 5.2. SEASONAL SETTLEMENT OF REPRESENTATIVE SPECIES GROUPS

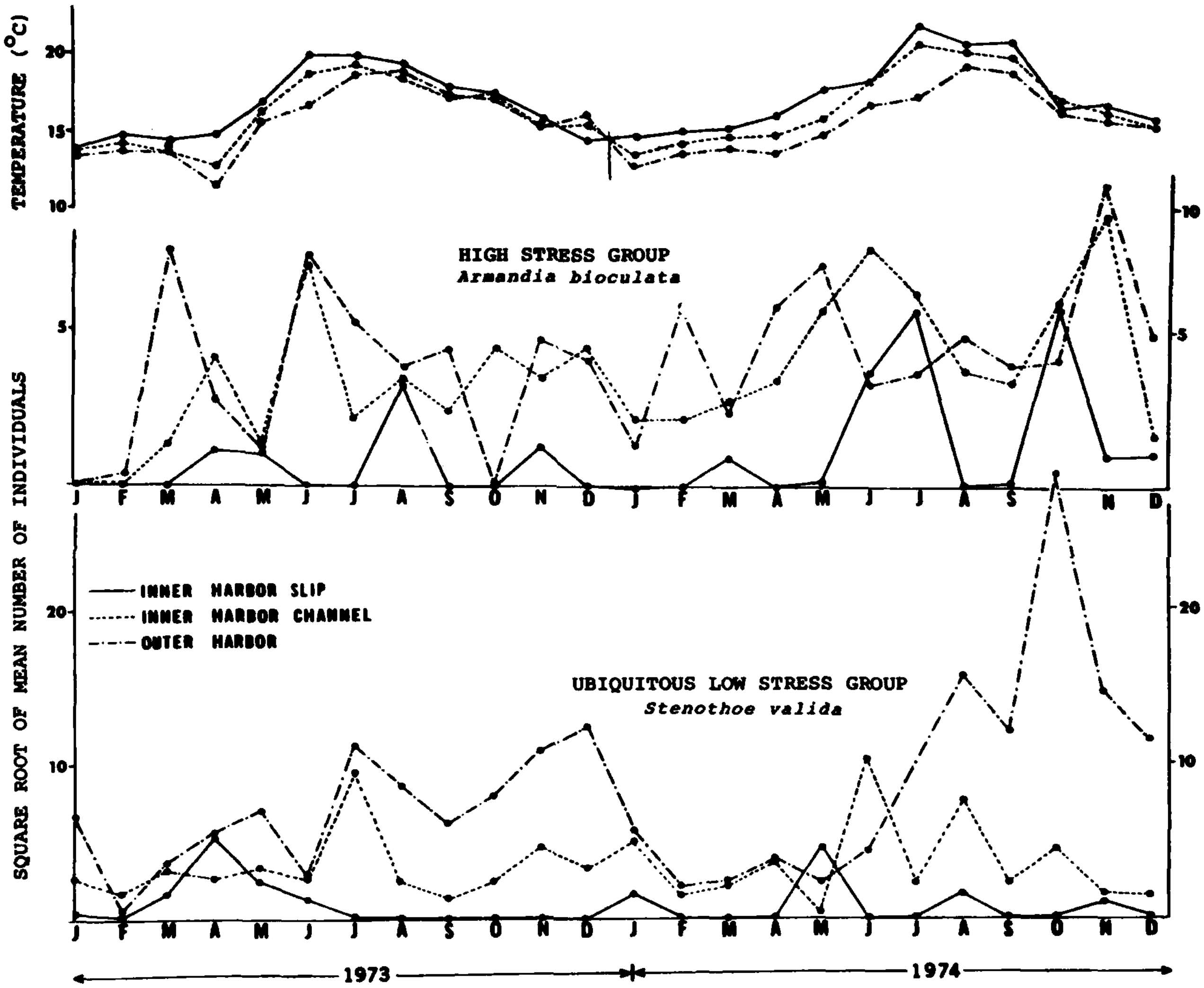


Figure 5.3. SEASONAL SETTLEMENT OF REPRESENTATIVE SPECIES GROUPS

Polydora limnicola, failed to show a significant correlation to temperature, except at stations B5 and C3. These sporadic correlations may be due to the influence of some other parameter not considered.

Table 5.4. Levels of Significance for Cross Correlations of Abundance with Temperature at Select Stations Within Los Angeles-Long Beach Harbors. Lag time is zero.

Species	Stations						
	A2	A6	B1	B5	B7	C2	C3
Capitella capitata				.01			.01
Ciona intestinalis	.01	.01				.05	.01
Corophium acherusicum	.01	.01	.01	.01	.01	.01	.01
Hydroides pacificus	.01	.01		.01	.01	.05	.01
Jassa falcata	.01	.05	.01	.01	.01	.01	.01
Polydora limnicola				.05			.05

Spatial Analysis

Site Groups: Four periods were classified, which included two periods of maximum settlement activity during the summers of 1973 (Figure 5.4, 5.5) and 1974 (Figure 5.6, 5.7) and two periods of reduced settlement activity during the winters of 1973 (Figure 5.8, 5.9) and 1974 (Figure 5.10, 5.11). The summer periods included 18 stations distributed throughout the study area. The same 18 stations were selected for both summer periods purposely to determine variation in the characterization of these sites at similar seasons. Similar stations were for the most part compared during the winter periods; however, the data during these periods were not as complete and required selection of other stations. In general, the classification of the study area on the basis of both summer and winter periods can be reduced to three major site groups and a fourth group of transitory stations which did not consistently group with any of the three major site groups. These site groups are herein defined in respect to their geographic location within the harbor as follows:

1. Inner harbor (C5, C6, C8, B6)

2. Inner harbor (main) channel (C2, B5, B7)

3. Outer harbor (A9, B8, B4, B3)

4. Transitory stations (A6, C7, B2, C3)

Additional stations which were included in this study but which were not represented in all four study periods were not included in the above site groups.

The inner harbor site group includes those stations predominantly in the dead-end slips of the innermost reaches of the harbor. Stations within these areas consistently grouped together and included C5, C6, C8 and B6 with the exception of stations C7 and A6. The C7 station grouped alone in the summer 1973 period suggesting a unique biotic characterization of this site. The A6 station at inner Fish Harbor is also a dead-end slip, although it is close to the outer harbor and consequently did not group with the inner harbor or dead-end slips consistently.

The stations comprising the inner harbor channel group consistently included those stations in the main channel around Terminal Island. These stations included C2, C3, B5 and B7. Stations A6 and B2 were included in this group in the summer 1974 period. Both of these stations are dead-end slips close to the outer harbor.

The outer harbor site group included those stations in the main water mass between the breakwater and Terminal Island (A9, B8, B3, B4).

Station B1, which is located just outside the harbor, was included in this analysis to represent the settlement activity occurring outside the harbor. Station B1 grouped apart from the harbor stations in both summer periods, but with stations A2 and A3 in the winter 1973 period. Station A2 and A3 are located within the outer harbor but are on the main channel from the breakwater entrance of Los Angeles Harbor.

Stations considered during the winter periods of 1973 (Figure 5.4,5) and 1974 (Figure 5.6,7) grouped similarly to the summer periods, into three major site groups which included (1) the outer harbor, (2) inner harbor channel, and (3) the inner harbor slips. In both winter periods, station B1 outside the harbor, grouped consistently with the outer harbor site group. Station A1, which is also outside the harbor, was included in the summer 1973 analysis and grouped with stations A6 and A7.

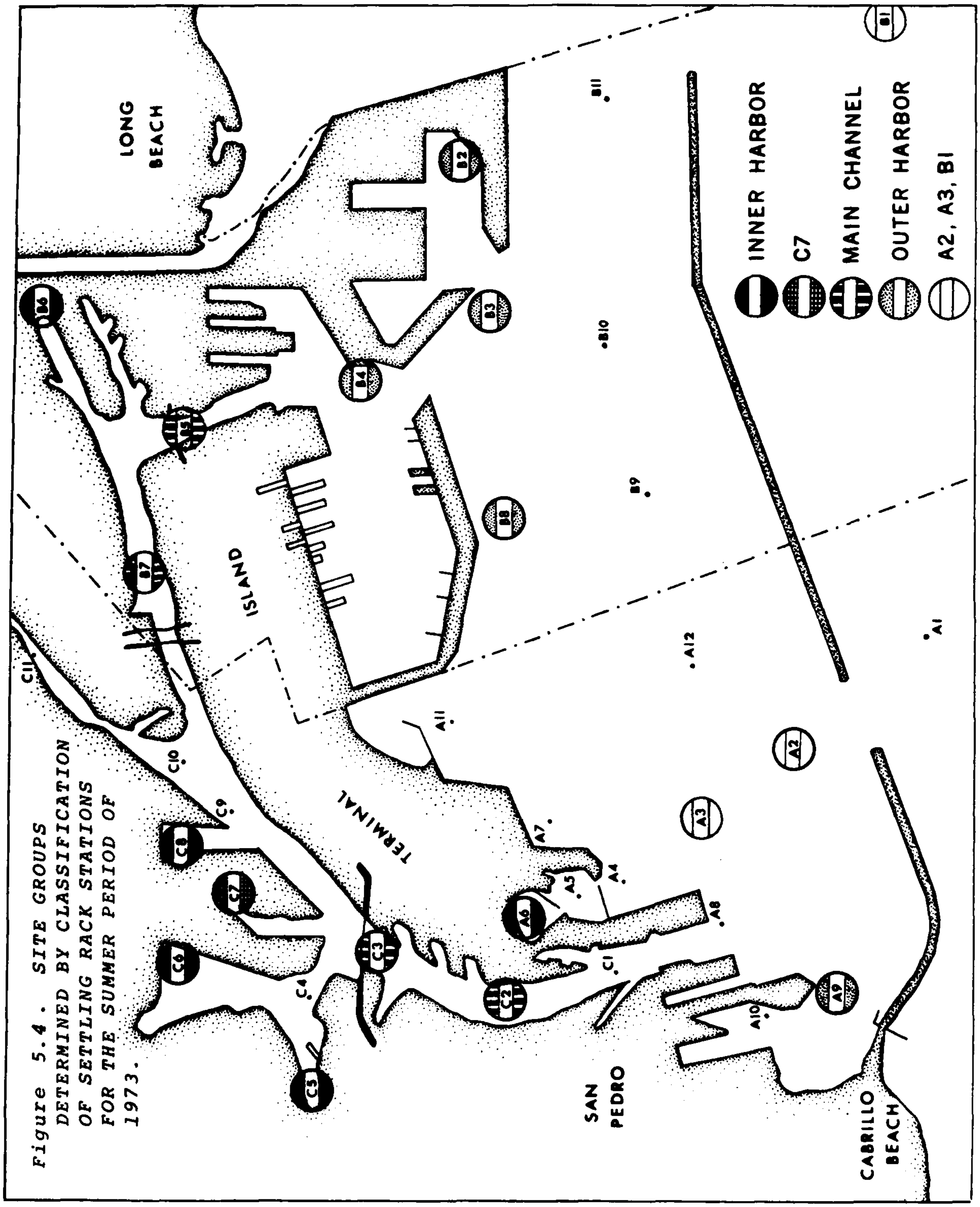
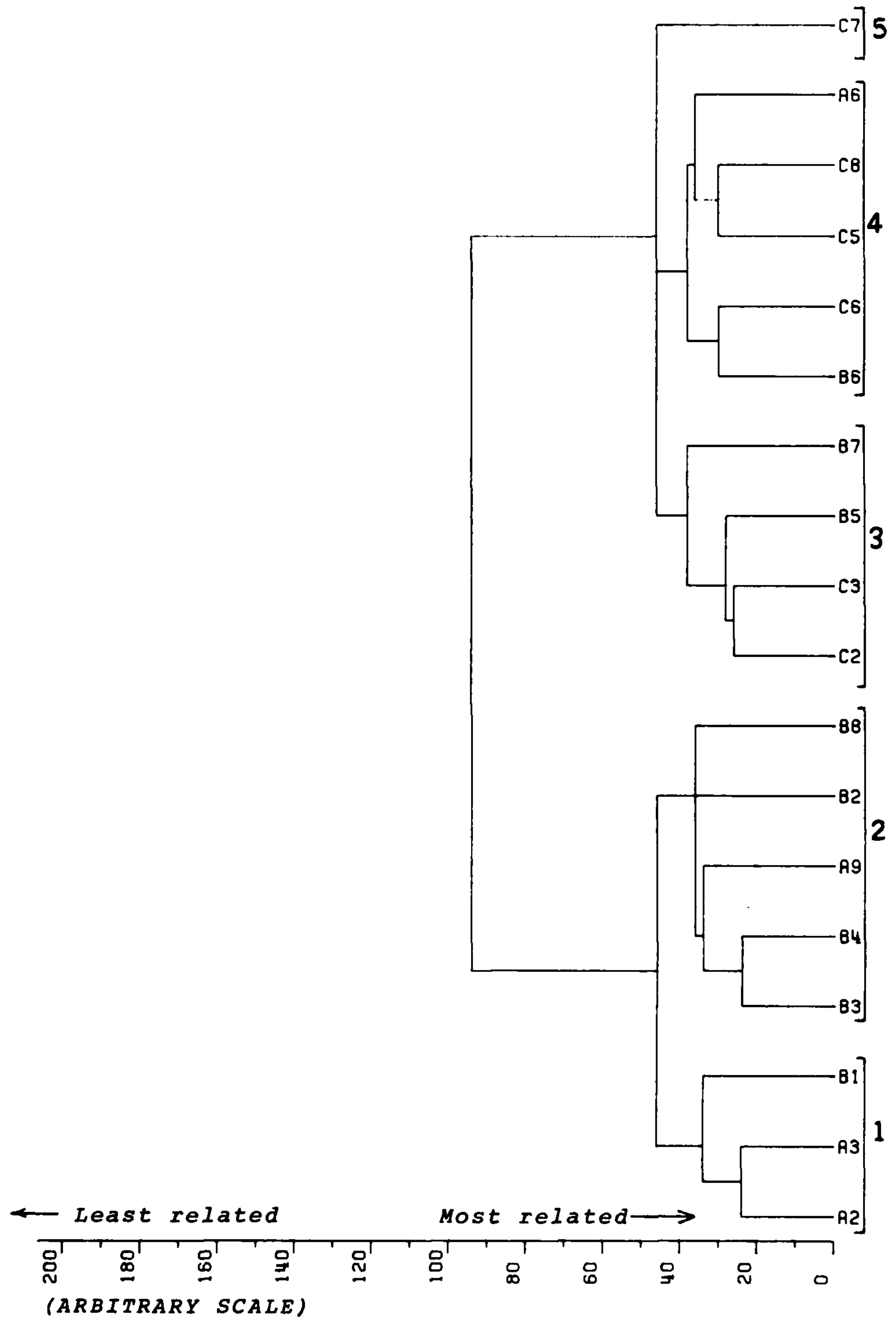


Figure 5.4. SITE GROUPS DETERMINED BY CLASSIFICATION OF SETTLING RACK STATIONS FOR THE SUMMER PERIOD OF 1973.

Figure 5.5
SETTLING RACK DATA FOR MAY,JUNE,JULY,AUG,SEPT, ● ALL STATIONS 73



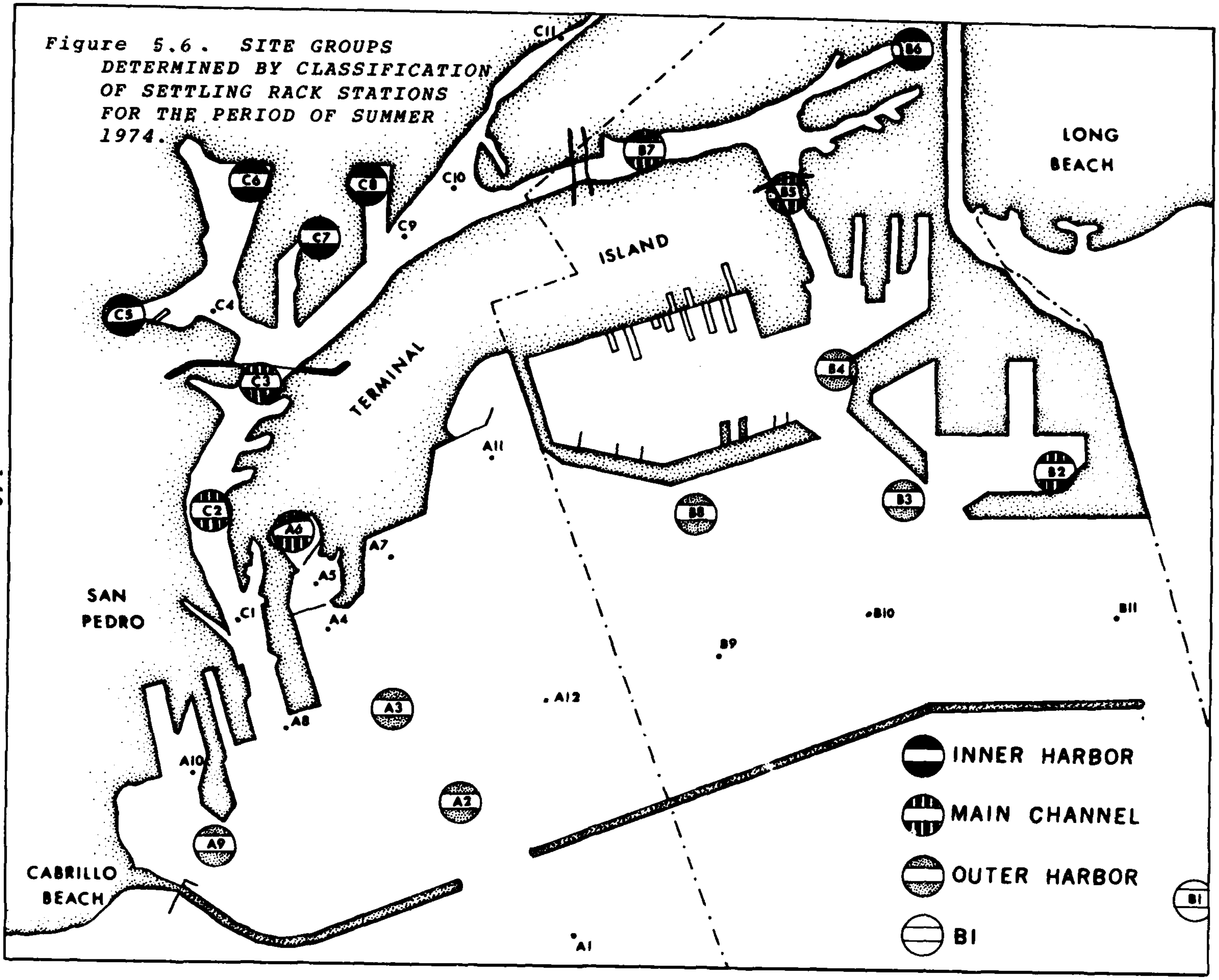


Figure 5.6. SITE GROUPS DETERMINED BY CLASSIFICATION OF SETTLING RACK STATIONS FOR THE PERIOD OF SUMMER 1974.

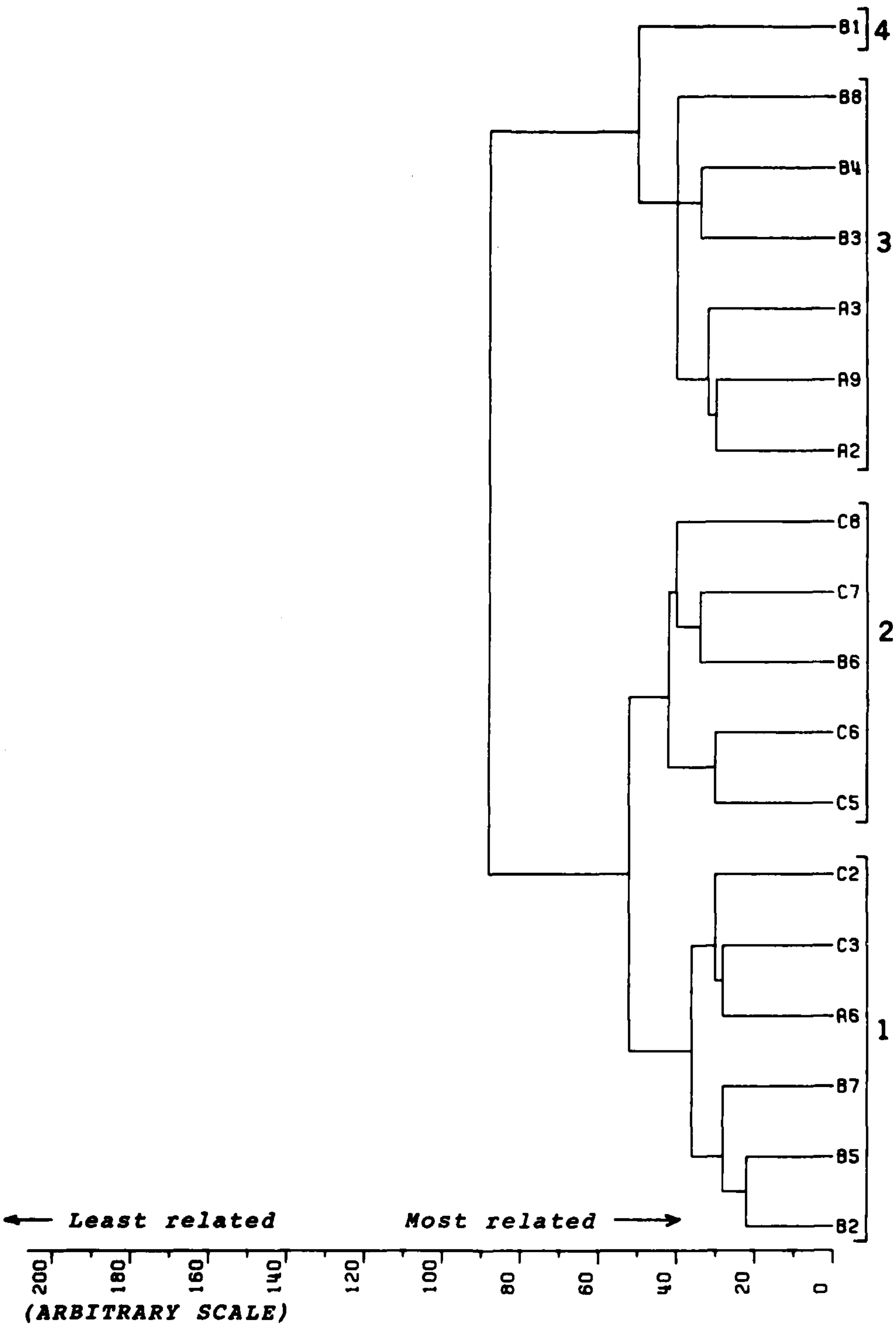


Figure 5.7 . Dendrogram

SETTLING RACK DATA FOR MAY, JUNE, JULY, AUG, SEPT, ● ALL STATIONS 74

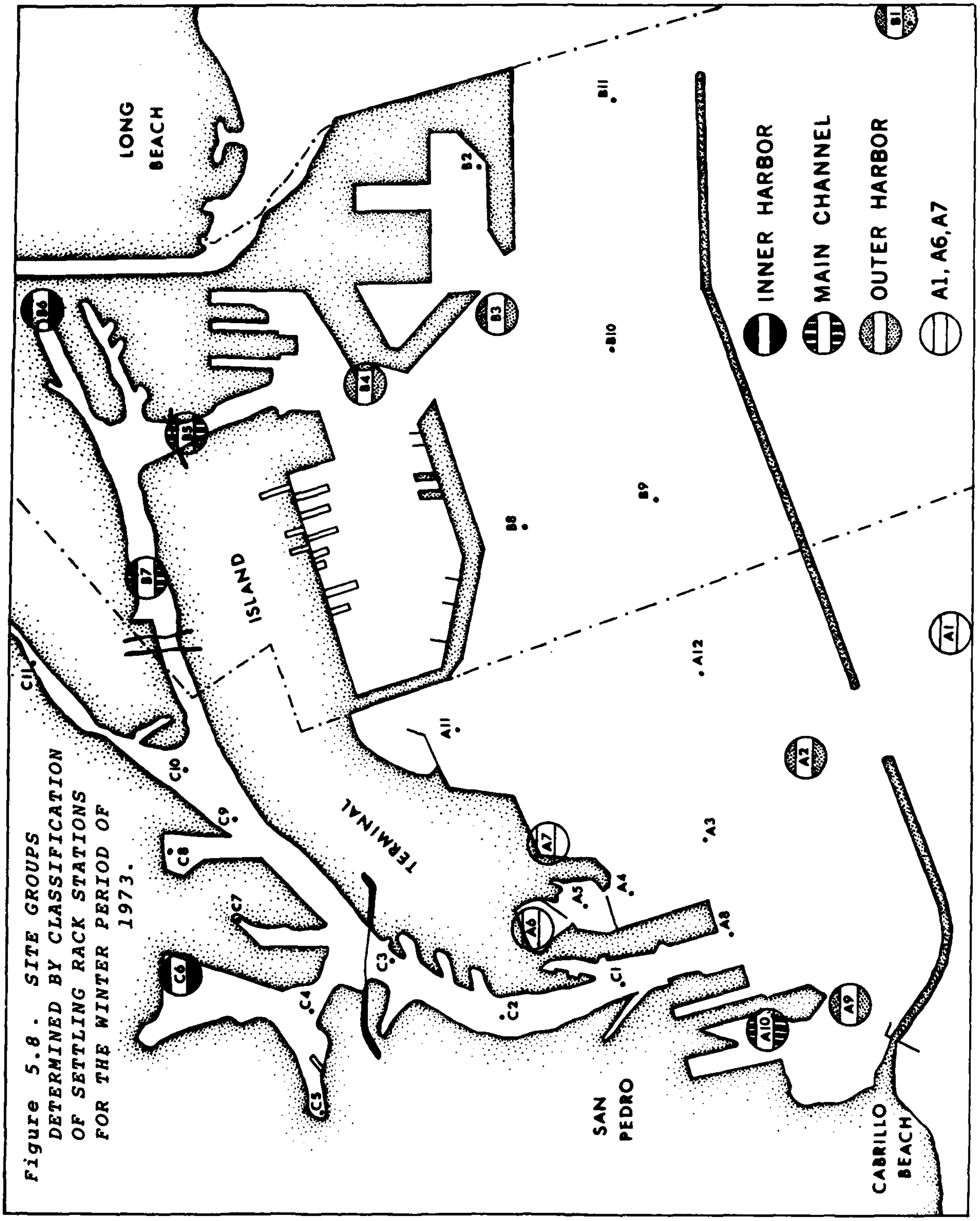


Figure 5.8. SITE GROUPS DETERMINED BY CLASSIFICATION OF SETTLING RACK STATIONS FOR THE WINTER PERIOD OF 1973.

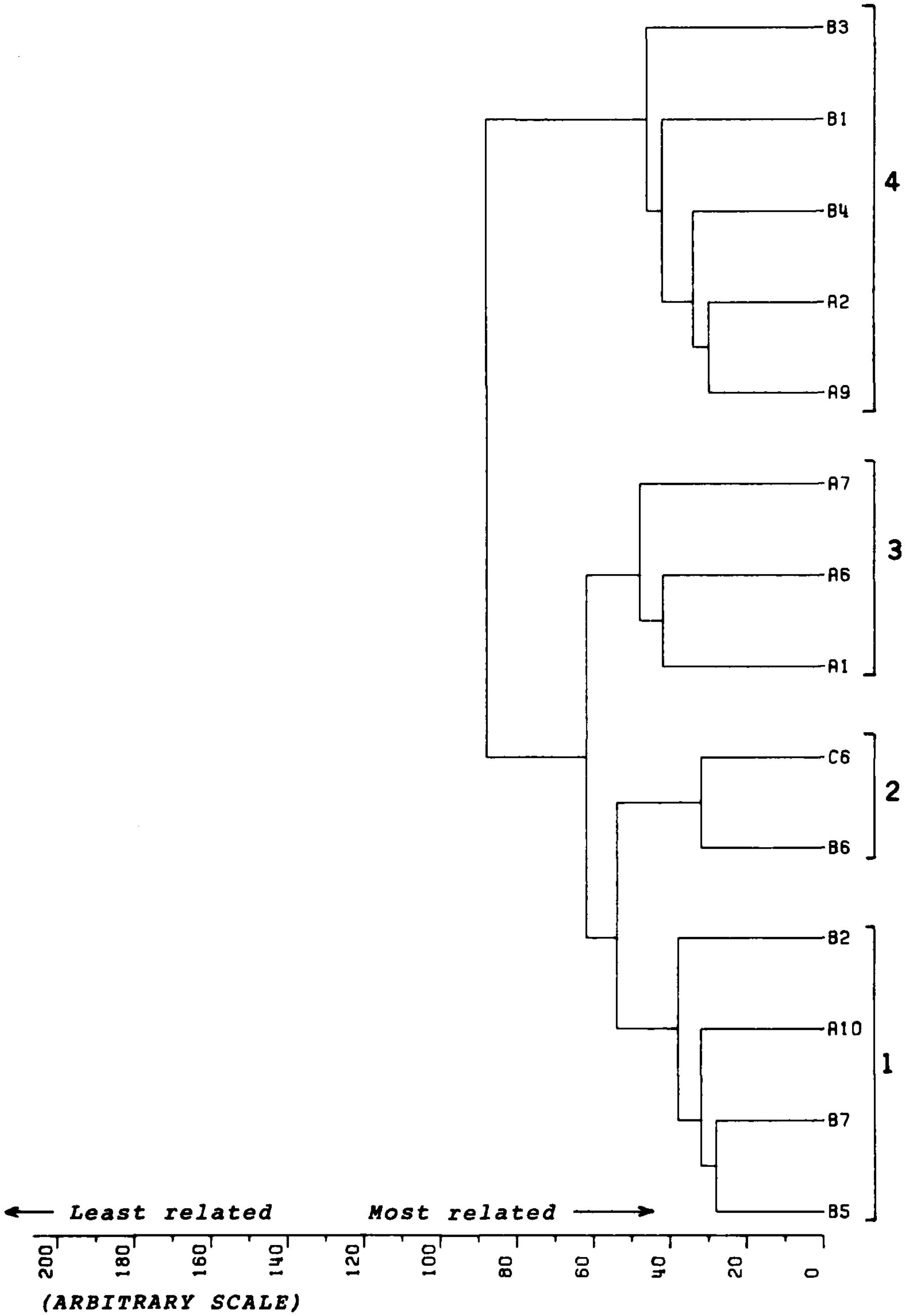


Figure 5.9. Dendrogram

SETTLING RACK DATA FOR DEC, JAN, FEB 73

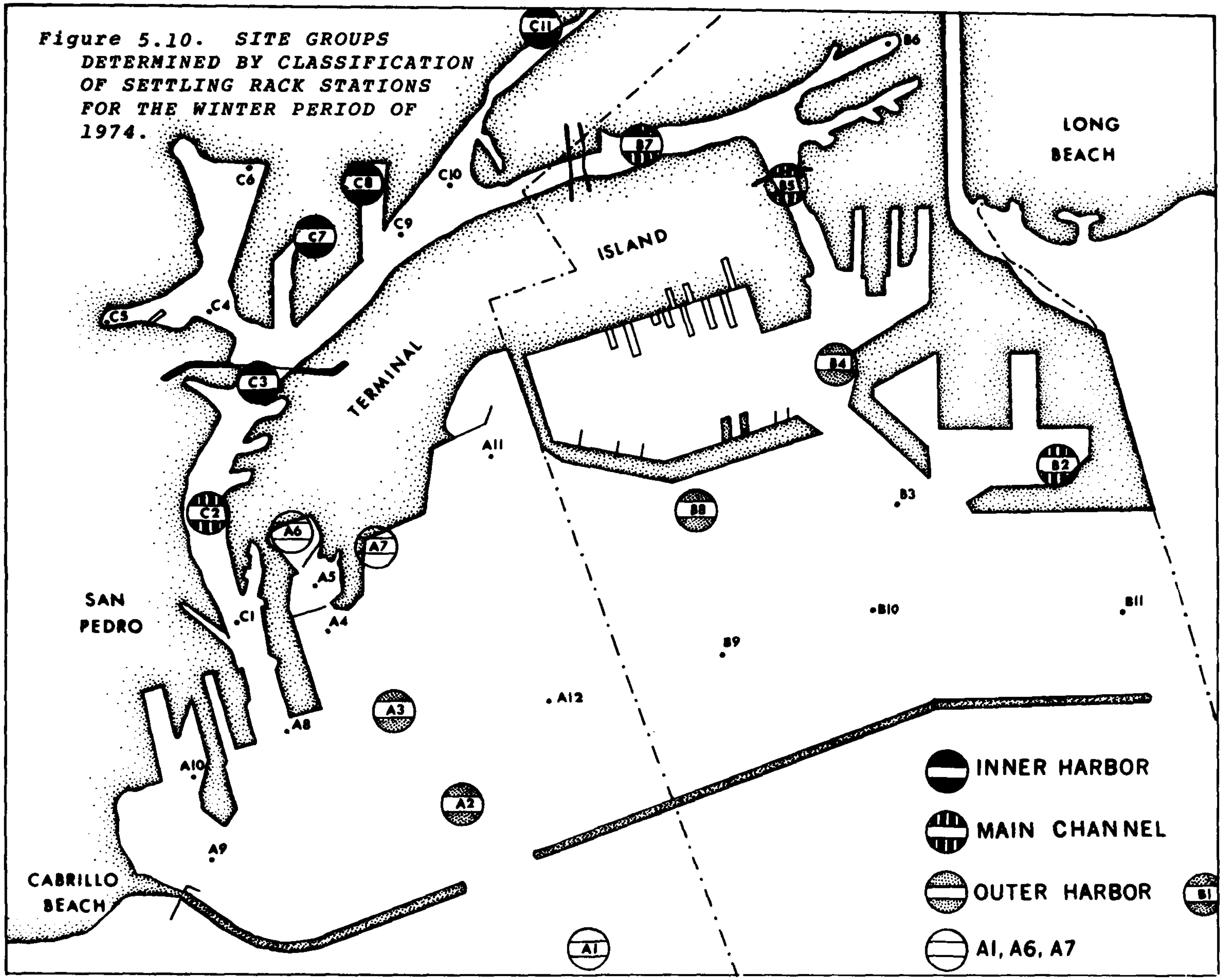


Figure 5.10. SITE GROUPS DETERMINED BY CLASSIFICATION OF SETTLING RACK STATIONS FOR THE WINTER PERIOD OF 1974.

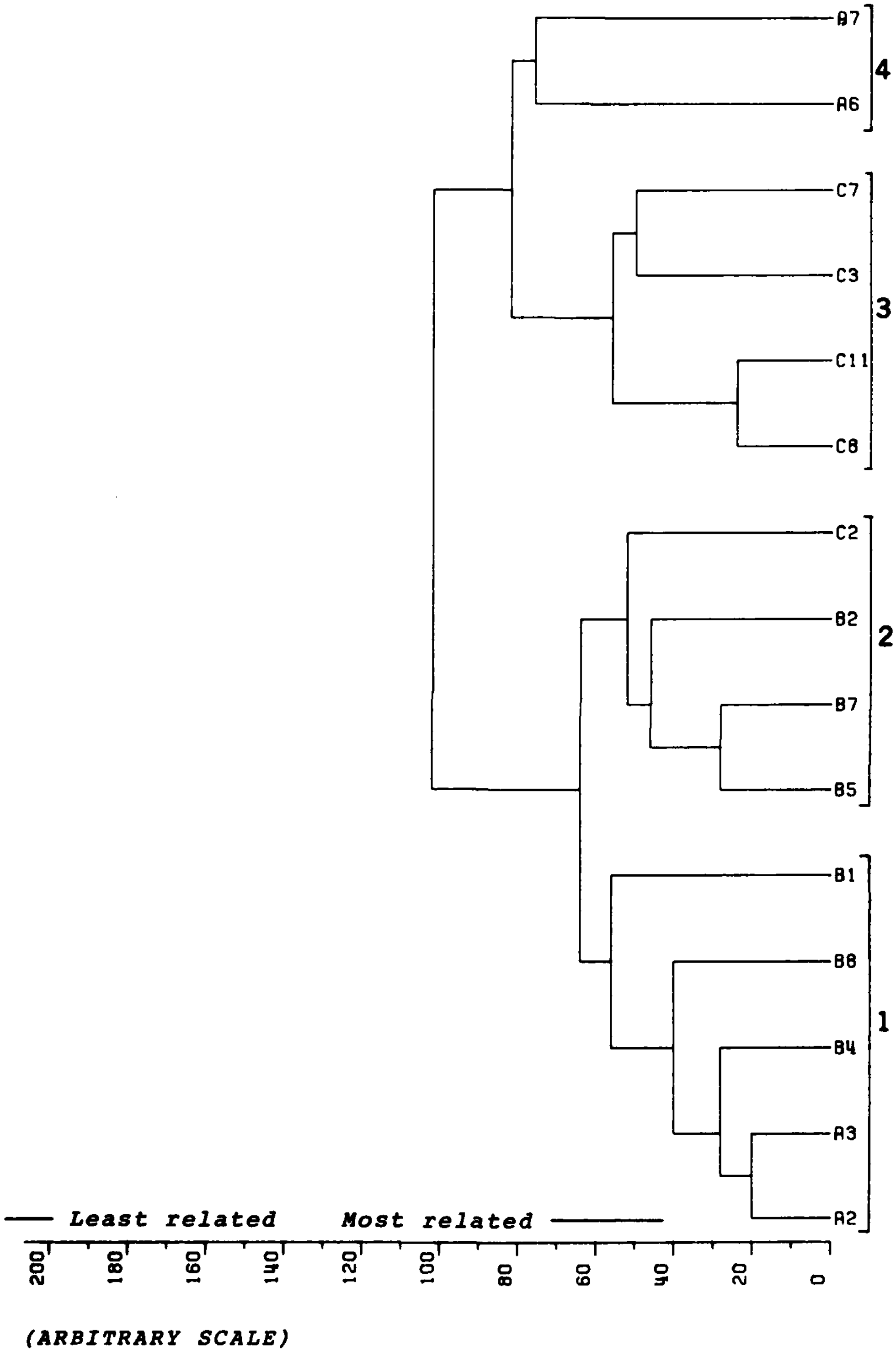


Figure 5.11. Dendrogram

SETTLING RACK DATA FOR DEC. JAN. FEB 74

Abiotic Parameters in Relation to the Station Groups: Station groups as previously determined for each study period were analyzed using a multiple discriminate analysis to distinguish and characterize each group in respect to the most significant abiotic components. Summary matrices of the mean abiotic measurements of each site group were generated for the two summer and two winter periods (Tables 5.5-5.8).

Summer 1973: The position of the site groups in respect to the abiotic parameters was determined using multiple discriminate analysis. The five site groups for this period, including station C7 as a distinct group, were well separated on the first discriminate axis (Figure 5.12). The most significant variables accounting for this separation included temperature and minimum dissolved oxygen. Station groups were ranked along a gradient from high oxygen-low temperature to low oxygen-high temperature. The outside station Bl was highest in dissolved oxygen and lowest in temperature followed by the outer harbor station group, the main harbor channel group and the inner harbor group, which was lowest in dissolved oxygen and highest in temperature. The major factors contributing to the second axis of separation indicated a gradient of salinity and turbidity. Although there was some overlap between the site groups, the outside and outer harbor site groups and the inner harbor slip station C7 were high in salinity and low in turbidity. The channel site group and inner harbor site groups, with the exception of station C7, were lower in salinity and higher in turbidity.

Summer 1974: The four site groups generated for this period separated well on the first discriminate axis as in the summer 1973 period (Figure 5.13). The first axis related to the temperature level and dissolved oxygen minimum. The inner harbor site group was characterized by low oxygen and high temperature. Increased oxygen and decreasing temperature occurred in the channel and the outer harbor site groups, respectively. Station Bl was highest in oxygen and lowest in temperature for this period. The outside harbor station Bl, high in chlorophyll *a* and low in turbidity, separated well along the second axis.

Winter 1973: The abiotic factors which characterized the site groups for the period were not as well defined as for the two summer periods previously discussed.

Discriminate analysis of the site groups showed temperature and dissolved oxygen to be important in separating groups on the first axis, and primarily salinity and chlorophyll *a* on the second axis (Figure 5.14). The inner harbor site

Table 5.5: MEAN ABIOTIC MEASUREMENTS OF THE 5 SITE GROUPS FOR THE SUMMER PERIOD OF 1973

	Site Groups				
	1 (A-2,A-3, B-1)	2 (Outer Harbor)	3 (Channel)	4 (Inner Harbor)	5 (C-7)
Temperature Mean	17.033	17.520	18.319	18.650	19.225
*Temperature Range	3.500	3.560	3.450	3.640	3.400
*Salinity Mean	3.514	3.511	3.508	3.510	3.514
*Salinity Min	3.507	3.506	3.503	3.499	3.506
Disolved Oxygen Mean	8.158	8.610	7.087	6.800	5.925
Disolved Oxygen Min	7.300	7.140	5.825	4.900	4.200
Turbidity Mean	0.803	0.775	0.724	0.656	0.665
*Biochem Oxg Demand Mean	1.289	1.238	1.288	1.616	1.131
Chlorophyll *a* Mean	4.068	3.703	4.286	5.377	3.860
Assimilation Ratio Mean	10.474	8.777	10.196	11.952	13.530

*Log Transformation

Table 5.6: MEAN ABIOTIC MEASUREMENTS OF THE 4 SITE GROUPS FOR THE SUMMER PERIOD OF 1974

	Site Groups			
	1 (Channel)	2 (Inner Harbor)	3 (Outer Harbor)	4 (B-1)
Temperature Mean	19.212	20.020	18.012	17.350
*Temperature Range	2.983	4.080	2.970	3.700
Salinity Mean	32.171	31.948	32.353	32.648
Salinity Min	30.917	31.120	31.283	31.500
Disolved Oxygen Mean	7.638	5.840	8.594	9.600
Disolved Oxygen Min	4.300	2.600	6.393	8.700
Turbidity Mean	0.649	0.678	0.707	0.827
Biochem Oxy Demand Mean	12.113	12.603	7.821	6.988
*Chlorophyll *a* Mean	1.902	1.208	1.447	0.289
*Assimilation Ratio Mean	2.591	2.604	2.407	2.962

*Log Transformation

Table 5.7: MEAN ABIOTIC MEASUREMENTS OF THE 3 SITE GROUPS FOR THE WINTER PERIOD OF 1973

	Site Groups		
	1 (Channel)	2 (B-1,B-4,B-3 A-2,A-9)	3 (Outer Harbor)
*Temperature Mean	2.609	2.601	2.603
Temperature Range	0.750	1.333	0.560
Salinity Mean	32.830	33.747	33.587
Disolved Oxygen Mean	6.583	7.511	8.270
Turbidity Mean	1.272	1.276	1.279
Biochem Oxg Demand Mean	1.407	1.914	1.356
*Chlorophyll *a* Mean	-0.896	-0.609	-0.436
Assimilation Ratio Mean	2.116	1.630	2.304

*Log Transformation

Table 5.8: MEAN ABIOTIC MEASUREMENTS OF THE 4 SITE GROUPS FOR THE WINTER PERIOD OF 1974

	Site Groups			
	1 (Outer Harbor)	2 (A-6,A-7)	3 (Main Channel)	4 (Inner Harbor)
Temperature Mean	13.894	13.899	14.193	14.135
*Temperature Range	3.323	4.249	2.454	2.184
Salinity Mean	32.292	31.062	33.071	32.996
Disolved Oxygen Mean	7.590	6.772	6.075	5.658
Turbidity Mean	0.780	0.685	0.768	0.732
Biochem Oxg Demand Mean	0.741	2.288	0.307	0.038
Chlorophyll *a* Mean	1.933	2.444	1.016	0.688
Assimilation Ratio Mean	16.459	17.783	13.636	16.142

*Log Transformation

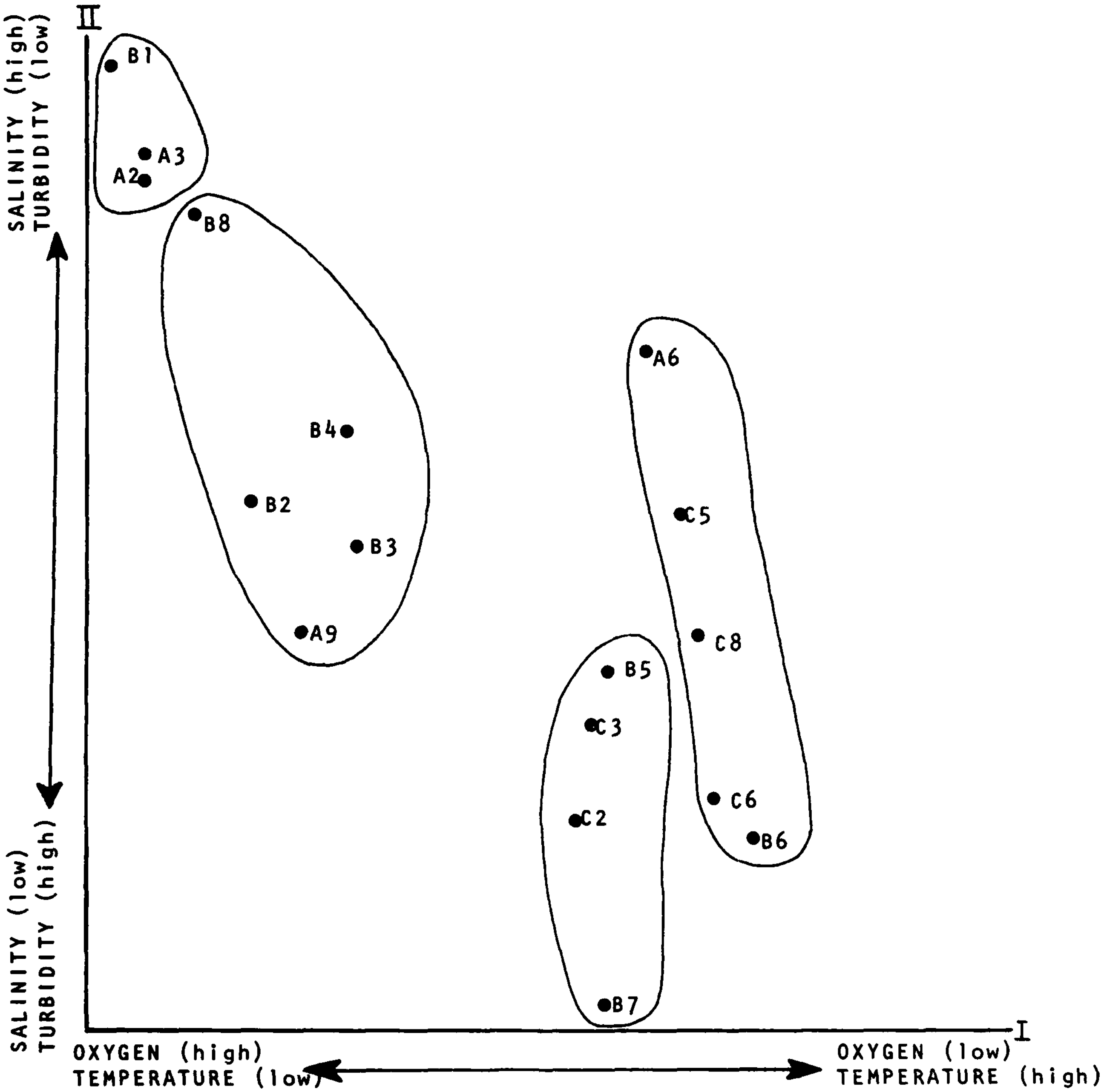


Figure 5.12. MAJOR ABIOTIC PARAMETERS CHARACTERIZING THE FIVE SITE GROUPS ALONG TWO MULTIPLE DISCRIMINATE AXES FOR THE SUMMER PERIOD OF 1973.

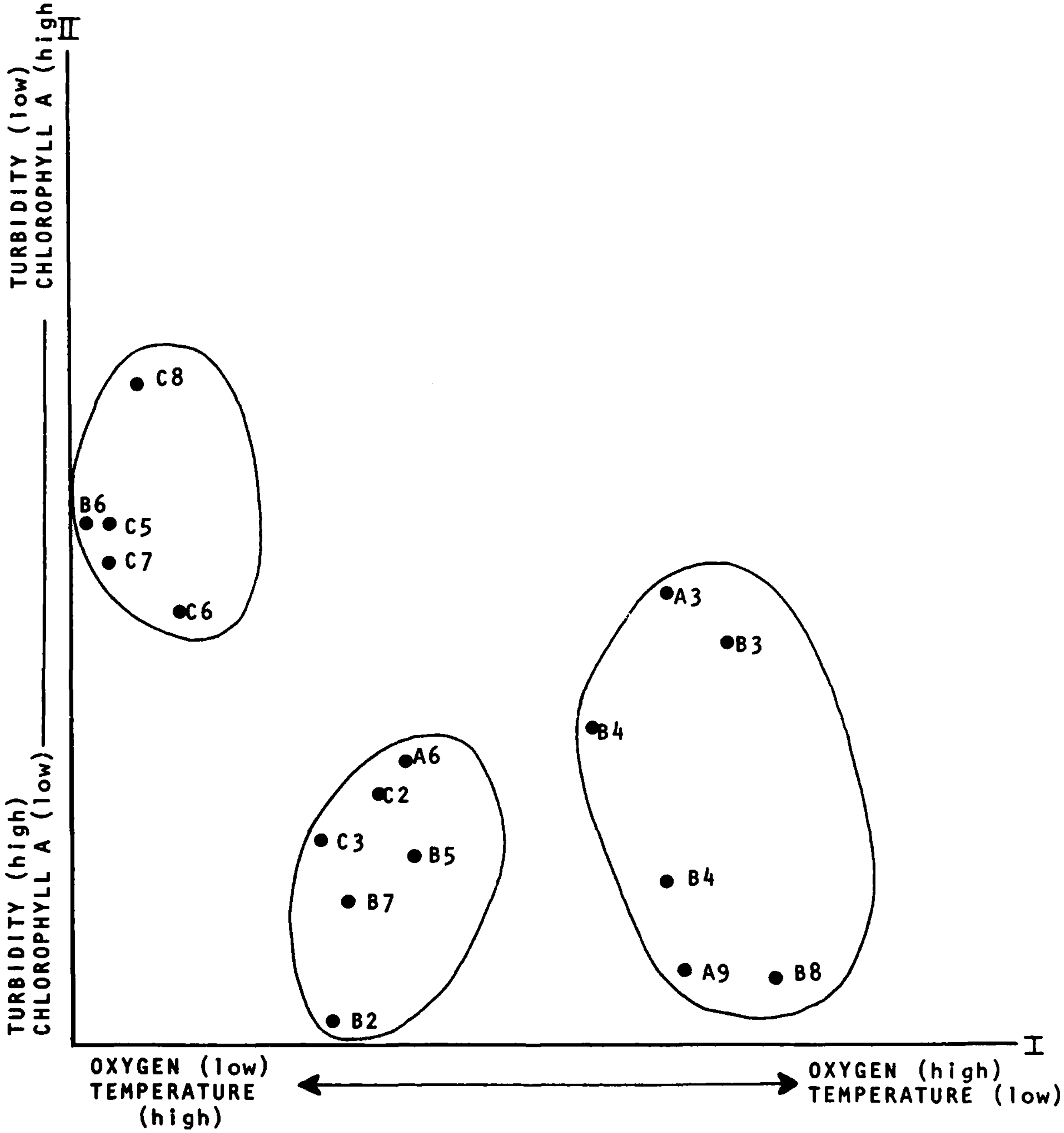


Figure 5.13. MAJOR ABIOTIC PARAMETERS CHARACTERIZING THE FOUR SITE GROUPS ALONG TWO MULTIPLE DISCRIMINATE AXES FOR THE SUMMER PERIOD OF 1974.

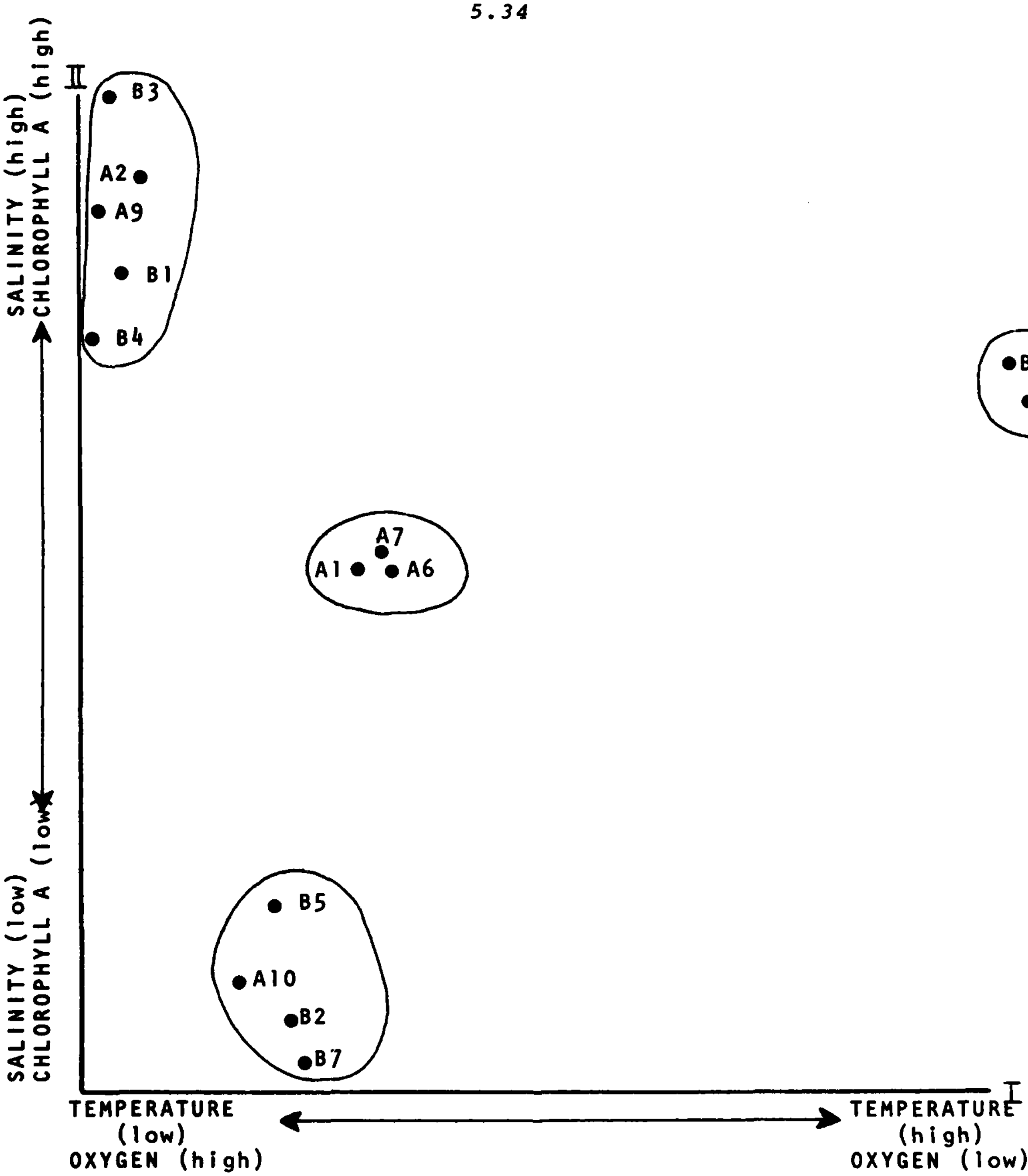


Figure 5.14. *MAJOR ABIOTIC PARAMETERS CHARACTERIZING THE FOUR SITE GROUPS ALONG TWO MULTIPLE DISCRIMINATE AXES FOR THE WINTER PERIOD OF 1973.*

group was highest in temperature and lowest in dissolved oxygen. The remaining site groups were more similar in temperature and dissolved oxygen and consequently did not separate well along the first axis. They separated well along the second axis, in which salinity and chlorophyll *a* were most important. The channel stations were lowest in salinity and chlorophyll *a* while the outer harbor stations were higher in salinity and chlorophyll *a*.

The site group consisting of B6 and C6, which are the dead-end slips, was so different abiotically that most of the group separation on the first two discriminate axes was between this group and the other three site groups.

To increase the resolution of discrimination between the remaining three groups the analysis was rerun without stations B6 and C6. In addition, a correlation of the ten abiotic variables yielded high correlations of salinity mean and salinity minimum; also dissolved oxygen mean and dissolved oxygen minimum were highly correlated. To avoid redundancy in the variables, the working abiotic matrix was reduced to eight variables without salinity minimum and dissolved oxygen minimum.

The multiple discriminate analysis produced a good separation of all three site groups on the first axis which was primarily related to salinity (Figure 5.15). The channel station group was lowest in salinity while the outer harbor group, consisting of stations B1, B3, A2, A9 and B4, were higher in salinity. The second axis was related to the dissolved oxygen levels, wherein the channel group was lowest in dissolved oxygen and the main outer harbor group was higher.

Winter 1974: The means and minimums of oxygen and salinity were highly intercorrelated; thus the analysis was run with the same eight variables as the winter 1973 period.

The first discriminate axis, which separated the inner harbor from the outer harbor groups, was mainly related to temperature, BOD and dissolved oxygen mean levels (Figure 5.16). Compared to the outer harbor group, the inner harbor and channel groups had higher temperatures and lower BOD and dissolved oxygen mean.

The two outer harbor groups were well separated on the second axis, which was mainly related to biochemical oxygen demand and turbidity. The outer harbor site group composed of stations A6 and A7 was more turbid and higher in biochemical oxygen demand.

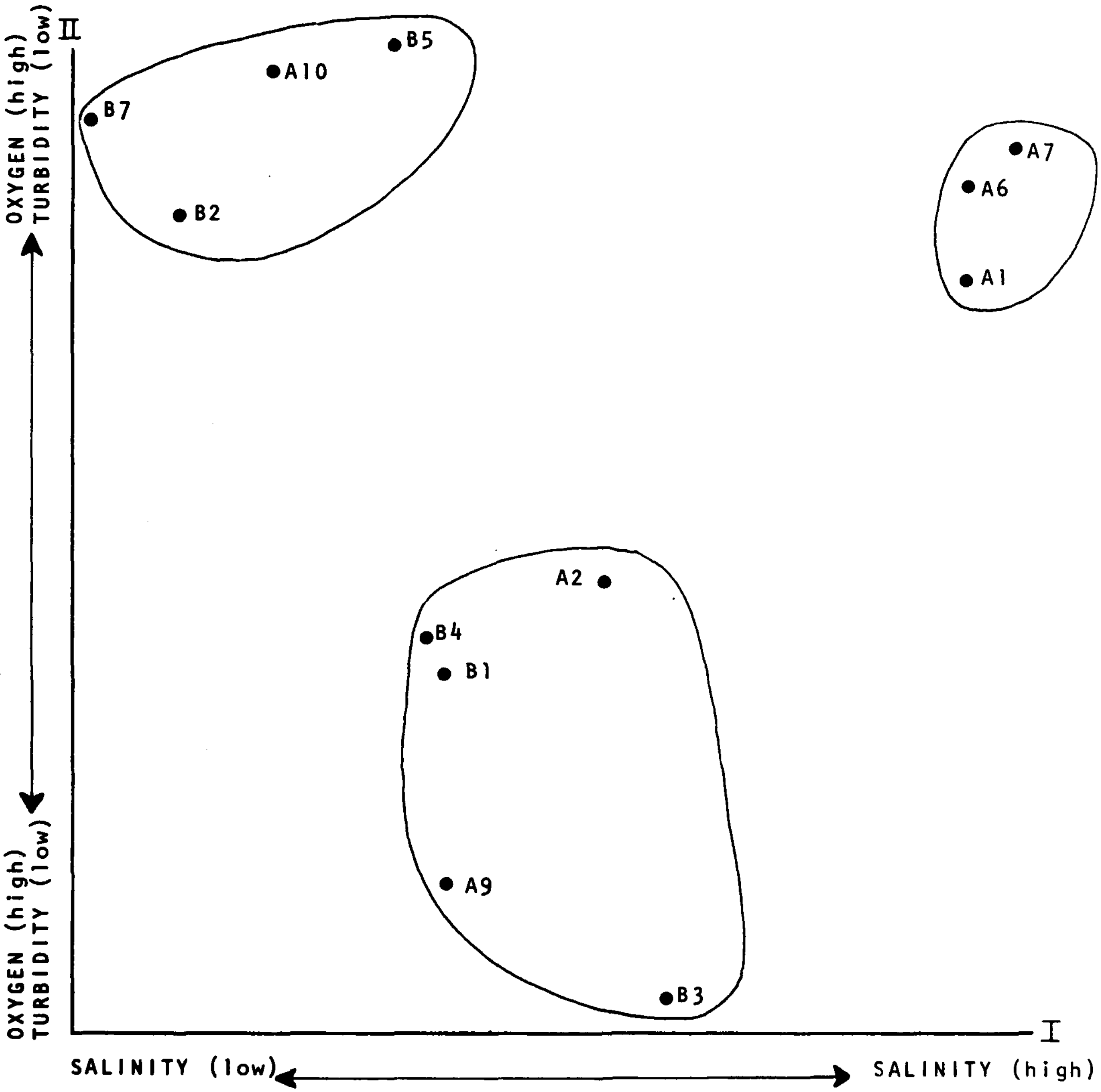


Figure 5.15. MAJOR ABIOTIC PARAMETERS CHARACTERIZING THE THREE SITE GROUPS ALONG TWO MULTIPLE DISCRIMINATE AXES FOR THE WINTER PERIOD OF 1973.

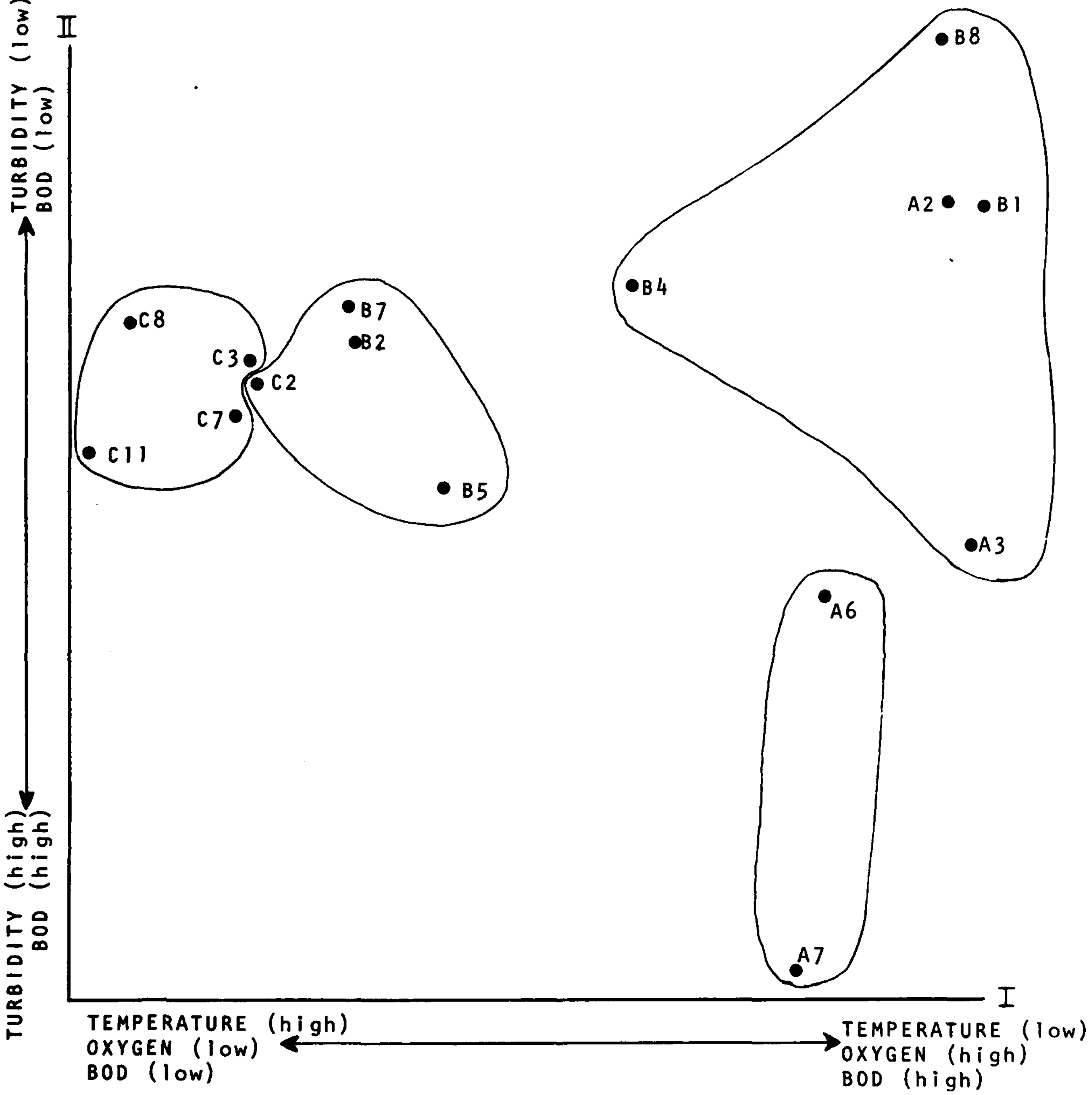


Figure 5.16. *MAJOR ABIOTIC PARAMETERS CHARACTERIZING THE FOUR SITE GROUPS ALONG TWO MULTIPLE DISCRIMINATE AXES FOR THE WINTER PERIOD OF 1974.*

Species Groups: The classification of species for each of the four study periods is shown in Figures 5.17-5.20. The distribution of the species groups throughout the station groups is shown in two-way Tables 5.10-5.13. Considerable overlap occurred in the distribution of the species in the previously described site groups. Species groups were defined in terms of an environmental stress gradient. The inner harbor and channel site groups were considered together as a high stress environment in terms of the higher temperature and lower dissolved oxygen recorded at these sites. A greater range in salinity was an additional component contributing to this high stress environment during the winter periods. The outer harbor and outside harbor site groups are combined in respect to their abiotic parameters as both groups were lower in temperature, and high in dissolved oxygen and salinity, constituting a low stress environment.

In Table 5.9 (below) five species groups and the stress factor assigned to each are defined in terms of their distribution within the high and low stress environments as defined above.

Table 5.9: ENVIRONMENTAL STRESS EVALUATION

Species Groups	Stress Factor	Occurrence
Low-stress	(1)	outside and outer harbor
Low-stress ubiquitous	(2)	throughout the harbor, concentrating in outer and outside harbor
Ubiquitous	(3)	throughout harbor
High-stress ubiquitous	(4)	throughout harbor, concentrating in inner harbor and channel
High-stress	(5)	inner harbor dead-end slips and channel

Each species group is herein defined by a stress factor on a scale from 1 to 5. Those species which occurred in two or more of the four study periods were ranked in respect to their occurrence in the above species groups. An environmental index was determined on the basis of the mean stress factor.

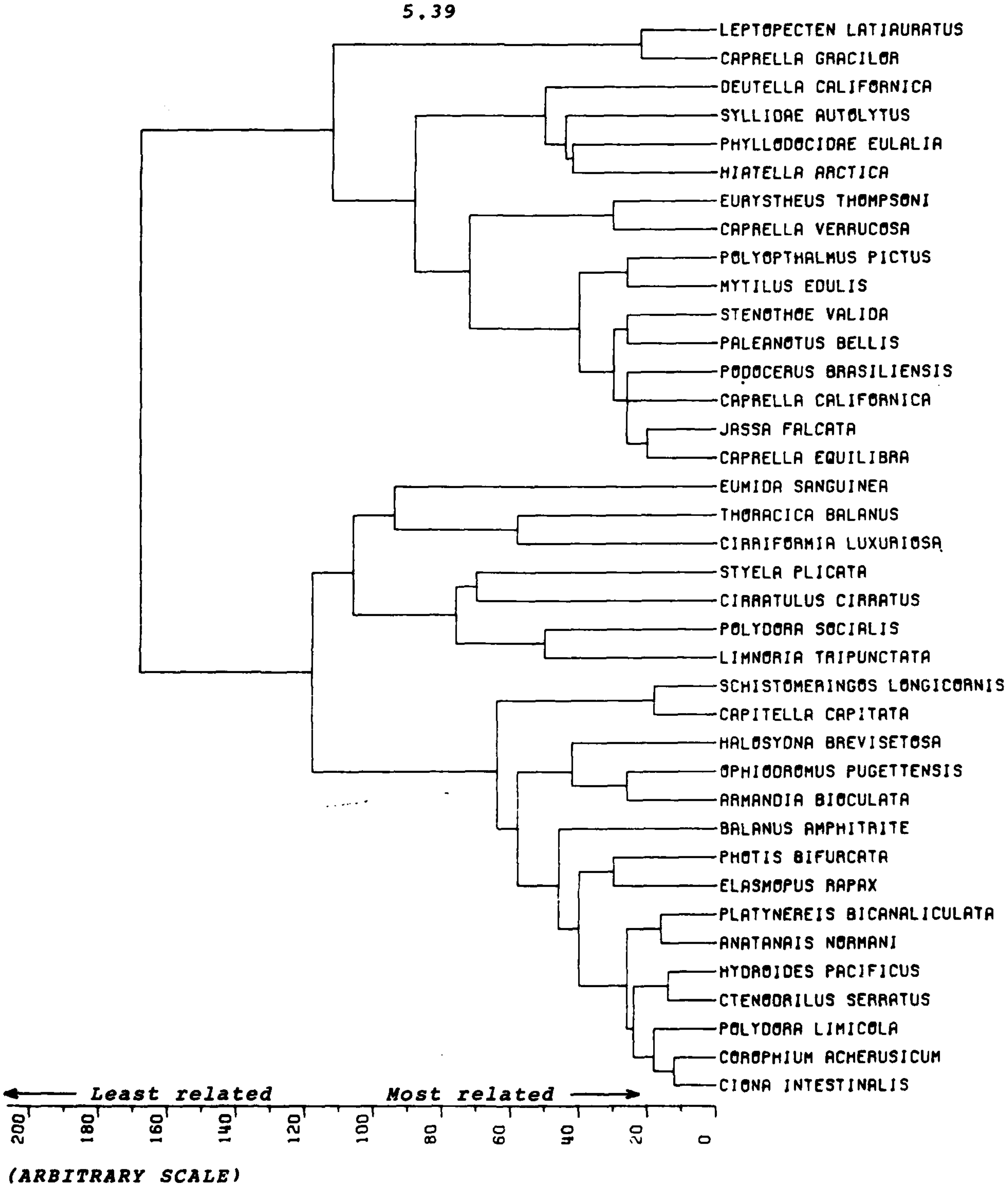


Figure 5.17: ***SPECIES CLASSIFICATION DENDROGRAM.***

SETTLING RACK DATA FOR MAY, JUNE, JULY, AUG, SEPT, ● ALL STATIONS 73

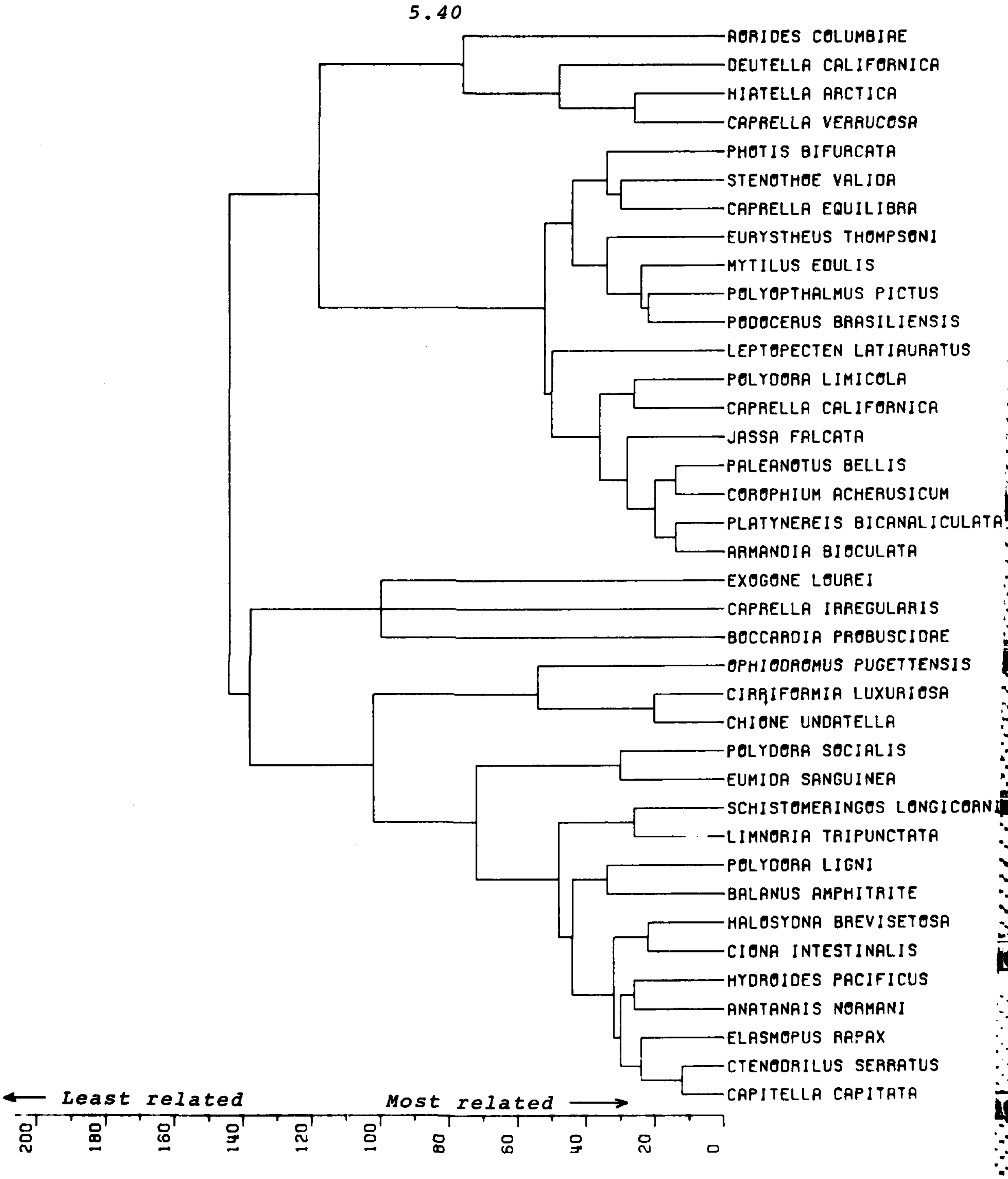
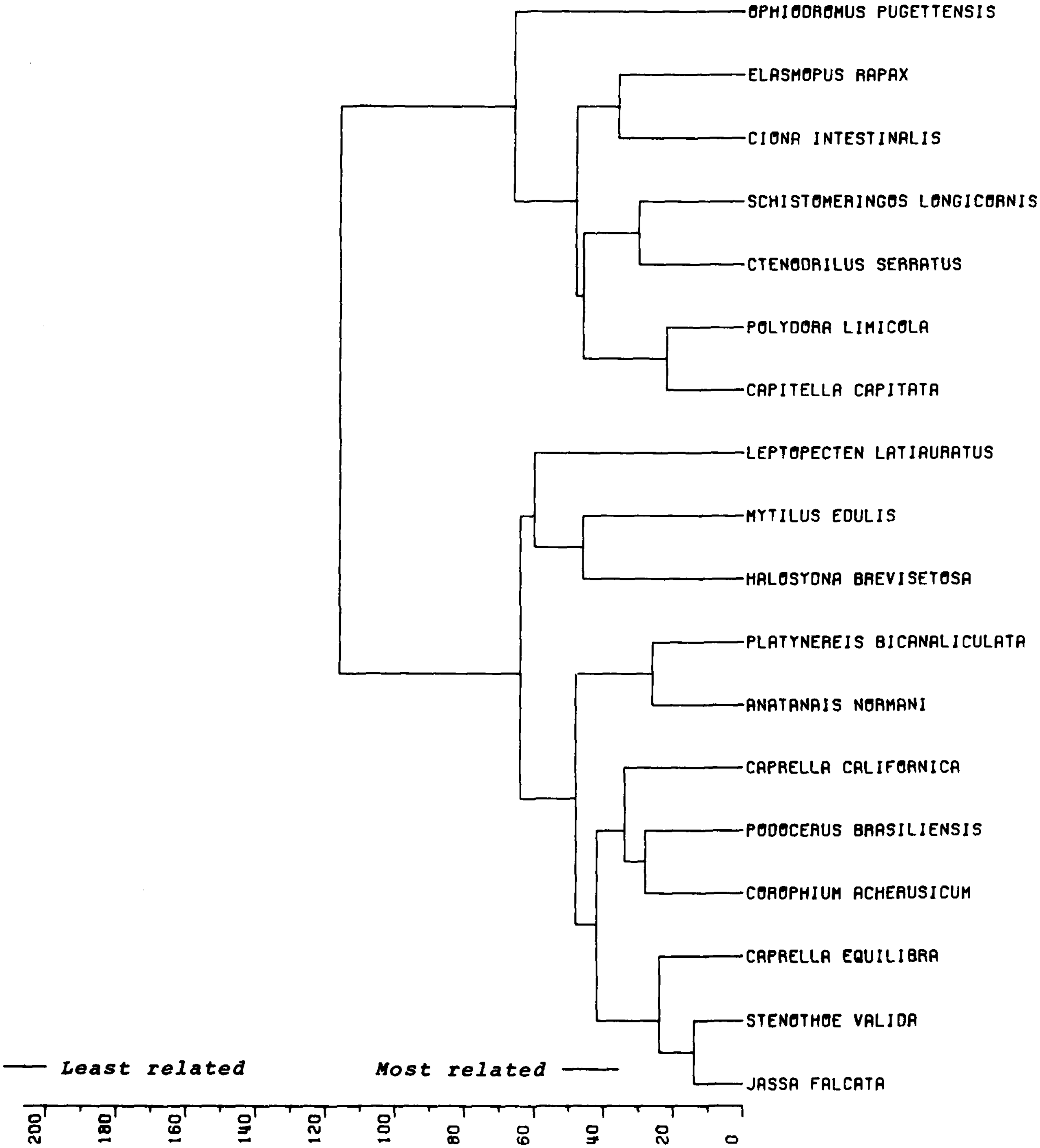


Figure 5.18: SPECIES CLASSIFICATION DENDROGRAM

SETTLING RACK DATA FOR MAY, JUNE, JULY, AUG, SEPT, • ALL STATIONS 74

(ARBITRARY SCALE)



(ARBITRARY SCALE)

Figure 5.19: SPECIES CLASSIFICATION DENDROGRAM
SETTLING RACK DATA FOR DEC, JAN, FEB 73

Figure 5.20: SPECIES CLASSIFICATION DENDROGRAM
SETTLING RACK DATA FOR DEC. JAN. FEB 74

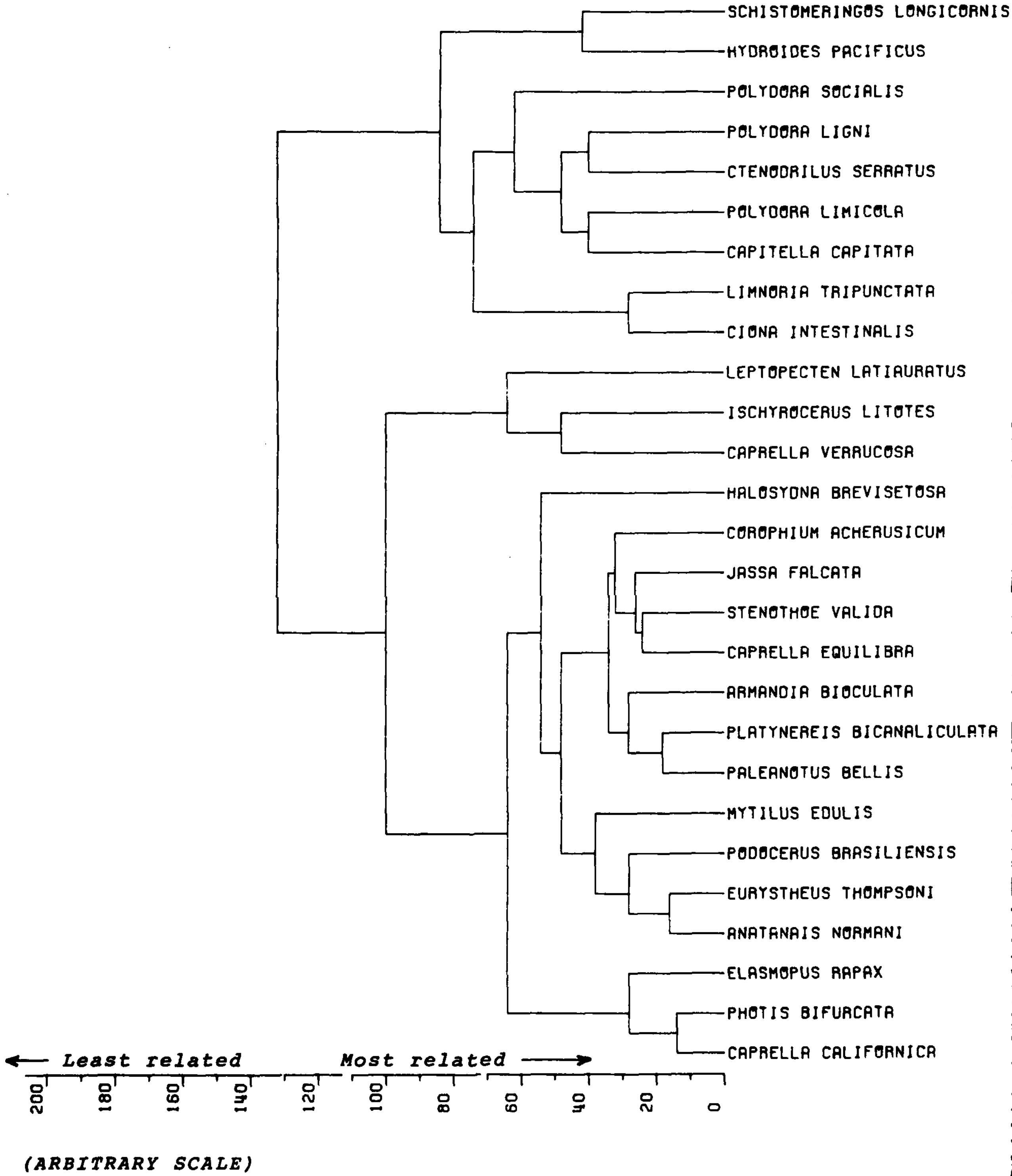


Table 5.10: <u>Two-way Table for the Summer 1973 Period</u>.
The columns correspond to the site classification in Figures 5.4, 5.5 and the rows correspond to the species classification in Figure 5.17

Species Groups**	Species	Site Groups																	
					Outer Harbor					Main Channel				Inner Harbor					
		A2	A3	B1	B3	B4	A9	B2	B8	C2	C3	B5	B7	B6	C6	C5	C8	A6	C7
U-HS	*Ciona intestinalis*	−	.	.	−	+	+	−	−	+	+	−	−	−	+	+	+	+	+
	Corophium acherusicum	−	−	.	−	−	−	−	.	+	+	+	−	+	+	+	*	−	+
	Polydora limicola	−	.	−	−	.	−	−	.	+	+	+	−	.	+	+	*	*	+
	Ctenodrilus serratus	−	−	.	−	.	.	+	−	+	+	*	−	+	+	+	−	+	−
	Hydroides pacificus	−	.	.	−	−	−	−	−	−	+	+	+	+	+	+	−	+	−
	Anatanais normani	−	−	−	+	.	−	−	−	−	+	+	+	.	−	−	*	−	
	Platynereis bicanaliculata	+	+	−	+	+	+	−	−	+	+	+	−	−	−	−	−	−	
HS	*Elasmopus rapax*		.		.	−	.	−	+	−	+	+	*	−	−	−	−	−	*
	Photis bifurcata		−		−	−	.	*	+	−	+	−	−	−	+		−	.	
	Balanus amphitrite					−		.	.	*	*	−	−	.	−	+	+	.	
	Armandia bioculata	−	+	.	+	+	+	−		+	−	+	+	.				+	−
	Ophiodromus pugettensis				−	−	+			+	−	+	+	−			+	+	−
	Halosydna brevisetosa	+	+	−		−	+		−	+			−	−		+	−	+	−
	Capitella capitata							−			+	+	−	−	−	+	+	+	−
	Schistomeringos longicornis											+	−	+	−	+	−	+	+
	Limnoria tripunctata										+		+			−	+		−
	Polydora socialis		−										−				−		−
	Cirratulus cirratus								+				−						
	Styela plicata			+			−	−					−						
	Cirriformia luxuriosa												−						+
	Thoracica balanus				−		+	.										−	+
	Eumida sanguinea											−						+	

** U-HS=ubiquitous-high stress; HS=high stress.

Table 5.10: (continued): <u>Two-way Table for the Summer 1973 Period</u> (continued). The columns correspond to the site classification in Figures 5.4, 5.5 and the rows correspond to the species classification in Figure 5.17

Species Groups**	Species	Site Groups																	
					Outer Harbor					Main Channel				Inner Harbor					
		A2	A3	B1	B3	B4	A9	B2	B8	C2	C3	B5	B7	B6	C6	C5	C8	A6	C7
U-LS	*Caprella equilibra*	-	-	+	*	+	+	+	-	+		+	.	.	-	-		.	.
	Jassa falcata	+	+	+	+	+	+	+	+	-	-	+	-	.	.	.	.	.	-
	Caprella californica	-	-	-	-	+	+	+	+	-	-	+	+	.	+			.	-
	Podocerus brasiliensis	-	-	-	+	-	+	+	*	+	+	+	.			.		-	.
	Paleanotus bellis	+	-	+	+	-	+	+	+	-		-		-		-	+	-	
	Stenothoe valida	+	-	+	+	-	+	-	+	.		+	+	.	.				
	Mytilus edulis	*	+	+	+	-	-	-	+	-	-	-	.				-		
	Polyopthalmus pictus	+	+		+	-	-	-	-		+	+	-						
LS	*Caprella verrucosa*	+	.		+	-			-										
	Eurystheus thompsoni	-	-		+	-			*	-									
	Hiatella arctica	+	-	+			-		-		-		-					-	
	Phyliodocidae eulalia	+	+				+	-	-				-						
	Syllidae autolytus		+	-			-		-										
	Deutella californica		-		-		+		+										
	Caprella gracilor	+	-	-															
	Leptopecten latiauratus	-		-															

** LS=low stress; U-LS= ubiquitous-low stress.

Table 5.11: Two-way Table for the Summer 1974 Period. The columns correspond to the site classification in Figures 5.6, 5.7 and the rows correspond to the species classification in Figure 5.18

Species Groups**	Species	Site Groups: Main Channel B2	B5	B7	A6	C3	C2	Inner Harbor C5	C6	B6	C7	C8	Outer Harbor A2	A9	A3	B3	B4	B8	B1
U-LS	*Capitella capitata*	+	+	+	.	+	−	−	−	+	+	*	−	.			.	−	
	Ctenodrilus serratus	+	+	−	−	+	+	−	−	+	+	+	−	.		−	.	−	
	Elasmopus rapax	+	+	+	.	+	+	.	−	−	+	−		−				+	
	Anatanais normani	+	+	+	−	−	−	−	+	+	.	+	−	+	−	+	.	−	−
	Hydroides pacificus	−	+	+	.	+	+	+	*	+	+	−	.	.	.	−	+	.	.
	Ciona intestinalis	−	−	+	−	+	+	*	+	−	+	+	.	−	.	−	−	−	
	Halosydna brevisetosa	−	−	−			+	+	+		+	+	−	+		+	+	−	
HS	*Balanus amphitrite*	.	−	+	+	+	+	−	+	−	−	.							
	Polydora ligni	−	.		+	*	+	*	+	.	*	.	.	−		−	.	−	.
	Limnoria tripunctata	.	.	+		+	−	+	−	−	+	+							
	Schistomeringos longicornis		+	−		.	−	+	−	+	+	+							
	Eumida sanguinea				−	+	−			+	+		−	−					
	Polydora socialis		−		−	−	+		.	+	*		+	−	.		.	.	
	Chione undatella									−	+							−	
	Cirriformia luxuriosa									−	+								
	Ophiodromus pugettensis									−	+	+	−	−					
	Boccardia probuscidae		−																
	Caprella irregularis																		−
	Exogene lourei	−										−							
U	*Armandia bioculata*	−	−	+	−	−	+		.	−	−	+	+	+	+	.	−	+	+
	Platynereis bicanaliculata	−	+	−	+	−	+	−	−	−	+	−	+	+	+	+	+	−	+
	Corophium acherusicum	−	−	−	−	−	+	+	−	−	+	*	−	−	−	+	−	+	−
	Paleanotus bellis	−	−	−	+	−	+	−	−	−	+	+	*	−	−	+	−	−	+
	Jassa falcata	+	+	+	−	−	+	.	−	.	.	.	*	+	*	+	−	−	+
	Caprella californica	+	+	+	+	+	+	.	−	.				−	+	−	+	−	
	Polydora limicola	+	+	.	+	+	+		−	−	+		−	+	−	+	.	.	
	Leptopecten latiauratus	+	−			+	+				−	−		+	−			+	−

** U-LS=ubiquitous-low stress; U=ubiquitous; HS=high stress.

Table 5.11: <u>Two-way Table for the Summer 1974 Period</u> (continued).
(continued): The columns correspond to the site classification in Figures 5.6, 5.7 and the tows correspond to the species classification in Figure 5.18

Species Groups**	Species	Site Groups: Main Channel B2	B5	B7	A6	C3	C2	Inner Harbor C5	C6	B6	C7	C8	Outer Harbor A2	A9	A3	B3	B4	B8	B1
U-LS	*Podocerus brasiliensis*	+	.	−	.	−	+						+	−	−	*	−	+	−
	Polyopthalmus pictus	+	.	−	.		−					−	+	+	−	*	*	.	+
	Mytilus edulis	−	−	.	.		−				.	−	*	+	+	+	−	+	+
	Eurystheus thompsoni	−	.		.		+					+	+	−	−	+	+	*	
	Caprella equilibra	+	−	−	−	.	+		.	.	−			+	.	*	+	.	+
	Stenothoe valida	.	.	+		.	+		−	.	.	.	+	+	.	+	−	*	*
	Photis bifurcata	+	+	−	.	.	*		−	.		.		.	.	.	−	*	+
LS	*Caprella verrucosa*			.									+		−	+		+	
	Hiatella arctica		.						.		+		+		+	+		+	
	Deutella californica	−			.		.							+	+	+		+	
	Aorides columbiae			−														+	

** LS=low stress; U-LS=ubiquitous-low stress.

Table 5.12: Two-way Table for the Winter 1973 Period.
The columns correspond to the site classification in Figures 5.8, 5.9 and the rows correspond to the species classification in Figure 5.19

Species Group**	Species	Site Groups: Main Channel B5	B7	A10	B2	Inner Harbor B6	C6	A1	A6	A7	Outer Harbor A9	A2	B4	B1	B3
U-LS	*Jassa falcata*	-	.	.	-		.	+	-	-	+	+	+	-	*
	Stenothoe valida	-	.	.	.		.	-	.	-	+	*	-	+	*
	Caprella equilibra	.			.		.	+	-		-	+	-	-	*
	Corophium acherusicum	-	.	-	.	+	-	.	+	+	+	*	-	-	+
	Podocerus brasiliensis		.		.			-		-	+	+	.	+	+
	Caprella californica	-	-	-	.					.	+	+	+		+
U	*Anatanais normani*	-	+	-		-		-				+	-	+	-
	Platynereis bicanaliculata	+	+	-	-	+		-	-	-	-	+	+	+	+
	Halosydna brevisetosa	.	.	-		-	-	.			-		-	.	*
	Mytilus edulis		.	.			.	-		*		.	-		*
	Leptopecten latiauratus			-	-							-		+	+
	Capitella capitata	-	-	-	-	+	-	-	*		.	-			
	Polydora limicola	-	-	.	-	-	*	-	*	+		-			
HS	*Ctenodrilus serratus*	+				+	+	.	.	-					
	Schistomeringos longicornis	-	+		-	+	-	-	-						
U-HS	*Ciona intestinalis*	+	-	+	+	+	+	-	-	.	+		-		.
	Elasmopus rapax	-	-	+		+	+						-		
	Ophiodromus pugettensis		-			+	-							+	

** U-LS=ubiquitous-low stress; U=ubiquitous; U-HS=ubiquitous-high stress; HS=high stress.

Table 5.13: Two-way Table for Winter 1974 Period. The columns correspond to the site classification in Figures 510 and 5.11 and the rows correspond to the species classification in Figure 5.20.

Species Group**	Species	Site Groups: Outer Harbor A2	A3	B4	B8	B1	Main Channel B5	B7	B2	C2	Inner Harbor C8	C11	C3	C7	A6	A7
U-HS	*Caprella californica*	–	–	+	–		+	–	+	.						
	Photis bifurcata	–	–	–	+		+	–	*							–
	Elasmopus rapax	–	–	–	+		+	+	+				–	–		
U-LS	*Anatanais normani*	+	+	–	*	–	–		–						–	
	Eurystheus thompsoni	+	+	–	+		.		.							
	Podocerus brasiliensis	+	*	–	+	–	–	.	+	.						
	Mytilus edulis	+	*	+	*	.	–		.		.	.	.	.	.	–
	Paleanotus bellis	+	+	+		+	–	–		–						
	Platynereis bicanaliculata	+	+	+	–	+	–	–		–			–	–		
	Armandia bioculata	–	+	+	–	–	–	–		–					+	
U	*Caprella equilibra*	–	–	+	+	*	–	–	–						–	
	Stenothoe valida	+	+	–	+	+	+	–	–	–			.			
	Jassa falcata	+	+	*	+	+	+	–	–	–		.	.		–	.
	Corophium acherusicum	+	+	+	–	–	+	–	–	–	–	+	–	–	–	.
	Halosydna brevisetosa	+	+	+					–	–			–			–
LS	*Caprella verrucosa*	+		–	+											
	Ischyrocerus litotes	–			*		.			.						
	Leptopecten latiauratus				+	–	+									
HS	*Ciona intestinalis*		.	+	–		*	+	–	–	–	–	–	–		
	Limnoria tripunctata						–	*	–		–	–	–	–		
U	*Capitella capitata*		–				–	–	–	–	–	–		+	*	
	Polydora limicola	–	+		–	–			–	–		–		–	*	–
	Ctenodrilus serratus	+	–	–			+	–					–	–	+	
	Polydora ligni	–					–	.						–	*	
	Polydora socialis						+	–		+			–			
	Hydroides pacificus							–		+				+		
	Schistomeringos longicornis			+				–						–		

** LS=low stress; U-LS=ubiquitous-low stress; U=ubiquitous; U-HS=ubiquitous-high stress; HS=high stress.

$$\text{Environmental Stress Index (ESI)} = \frac{\sum \text{(Stress Factors)}}{N}$$

N = number of study periods

Species with a high ESI would be found primarily in high stress environment of the study area and would include *Balanus amphitrite* and *Limnoria tripunctata* (Tables 5.11 to 5.14). Those species that occurred predominantly in a low stress environment would include *Caprella verrucosa* and *Hiatella arctica*.

Species grouped similarly in both summer periods into the above five species groups in approximately equal proportions (Table 5.15). A ubiquitous group of 8 species was not evident in the summer 1973 period. The high stress group was characterized by only four species in the summer 1974 period as opposed to 8 species in the previous period.

Approximately 50% of the species were retained in similar groupings for both summer periods. Fourteen species consistently occurred within the same species groups in both summer periods during 1973-74. Those species which did not consistently group similarly occurred usually in a closely related group. For example, *Corophium acherusicum, Platynereis bicanaliculata* and *Polydora limnicola,* which occurred in the high-stress ubiquitous group for the summer 1973 period, did not occur in the summer 1974 group. These species were more uniformly distributed during the summer 1974 period, thus they were grouped as ubiquitous species. Similarly, three species, *Caprella californica, Jassa falcata* and *Paleonotus bellis,* were more uniformly distributed in the following summer period and occurred in the ubiquitous species group. Four of the seven species comprising the ubiquitous low stress group occurred similarly in both winter periods.

Comparison of Settling Rack and Piling Fauna

Because little or no succession occurs during any one-month period, the settling rack biota differ from those communities sampled by scraping pilings at various depths. A number of piling surveys carried out in the inner Los Angeles Harbor were compared to the settling rack surveys; the pilings showed a reduced number of taxa of "fouling" organisms. This may be due to differences in the substrate material, such as treated or untreated wood or concrete, or to competition and succession of the fauna.

Comparison was made of a composite of the dominant piling fauna encountered in six piling surveys conducted at Slip 1,

Table 5.14: Species Occurring in the Same Species Groups for Both Summer (June, July, August) Periods of 1973 and 1974.

Species	Environmental Stress
Caprella verrucosa	low
Deutella californica	low
Hiatella arctica	low
Mytilus edulis	ubiquitous-low
Podocerus brasiliensis	ubiquitous-low
Polyopthalmus pictus	ubiquitous-low
Stenothoe valida	ubiquitous-low
Anatanais normani	ubiquitous-high
Ciona intestinalis	ubiquitous-high
Ctenodrilus serratus	ubiquitous-high
Hydroides pacificus	ubiquitous-high
Balanus amphitrite	high
Schistomeringos longicornis	high
Ophiodromus pugettensis	high

Table 5.15: Species Groups Occurring in the Summer (June, July, August) periods of 1973 and 1974.

1973	1974
Low Stress	
Caprella verrucosa	*Aorides columbiae***
Caprella gracilor	*Caprella verrucosa*
Deutella californica	*Deutella californica*
Hiatella arctica	*Hiatella arctica*
Leptopecten latiauratus	
Eulalia sp.**	
Autolytus sp. **	
Eurystheus thompsoni	
Low Stress - Ubiquitous	
*Caprella californica**	*Caprella equilibra*
*Jassa falcata**	*Eurystheus thompsoni*
Mytilus edulis	*Mytilus edulis*
*Paleanotus bellis**	*Photis bifurcata*
Podocerus brasiliensis	*Podocerus brasiliensis*
Polyopthalmus pictus	*Polyopthalmus pictus*
Stenothoe valida	*Stenothoe valida*
Ubiquitous	
Polydora limnicola	*Armandia bioculata*
Paleanotus bellis	*Caprella californica*
Platynereis bicanaliculata	*Corophium acherusicum*
	Jassa falcata
	Laptopecten latiauratus
Ubiquitous - High Stress	
Anatanais normani	*Anatanais normani*
Ciona intestinalis	*Ciona intestinalis*
*Corophium acherusicum**	*Elasmopus rapax*
Ctenodrilus serratus	*Halosydna brevisetosa*
Hydroides pacificus	*Hydroides pacificus*
*Platynereis bicanaliculata**	*Ctenodrilus serratus*
Polydora limnicola	*Capitella capitata*

(continued)

* Present in other species group.
** Not present in other survey.

Table 5.15 (continued)

1973	1974
High Stress	
*Armandia bioculata**	*Balanus amphitrite*
Balanus amphitrite	*Boccardia proboscida***
*Capitella capitata**	*Cirriformia luxuriosa***
*Elasmopus rapax**	*Eumida sanguinea***
*Halosydna brevisetosa**	*Limnoria tripunctata*
Ophiodromus pugettensis	*Ophiodromus pugettensis*
Photis bifurcata	*Polydora ligni*
Schistomeringos longicornis	*Polydora socialis*
	Schistomeringos longicornis

* Present in other species group.
** Not present in other survey.

Slip 5 and East Basin Channel in Los Angeles Harbor under other funds with the numerically dominant settling rack fauna of proximal settling rack station (C7). This showed that there were nine species of dominant fauna in common to both stations, and a 60% agreement between those fauna which are part of an active climax piling community with those of a newly settled community, seeded monthly from the water column onto the settling racks.

Table 5.16 shows a comparison between both piling and settling rack faunal groups, ranked according to their respective numerical abundance. Many of the fauna, like *Corophium acherusicum* and *Jassa falcata*, are distributed ubiquitously within the harbors and would be expected to be present at any station. However, other species such as the barnacle *Balanus amphitrite, Limnoria tripunctata* and *Elasmopus rapax,* are relatively restricted in their distribution and concentrated in their numbers at station C7. For this reason, the selection and comparison of settling rack station C7 was felt to be very representative of the settling fauna, rather than a composite of the entire harbor (Figure 5.21). The difference in numerical abundance ranking illustrates the possible effects of succession on the pilings. *Limnoria tripunctata, Anatanais normani* and *Jassa falcata* increase in numerical abundance rank on the pilings, while *Corophium acherusicum, Ciona intestinalis, Polydora limnicola, Hydroides pacificus,* and *Balanus amphitrite* decrease in numerical abundance rank. *Mytilus edulis,* considered typical of the piling community, did not occur on the C7 racks.

DISCUSSION

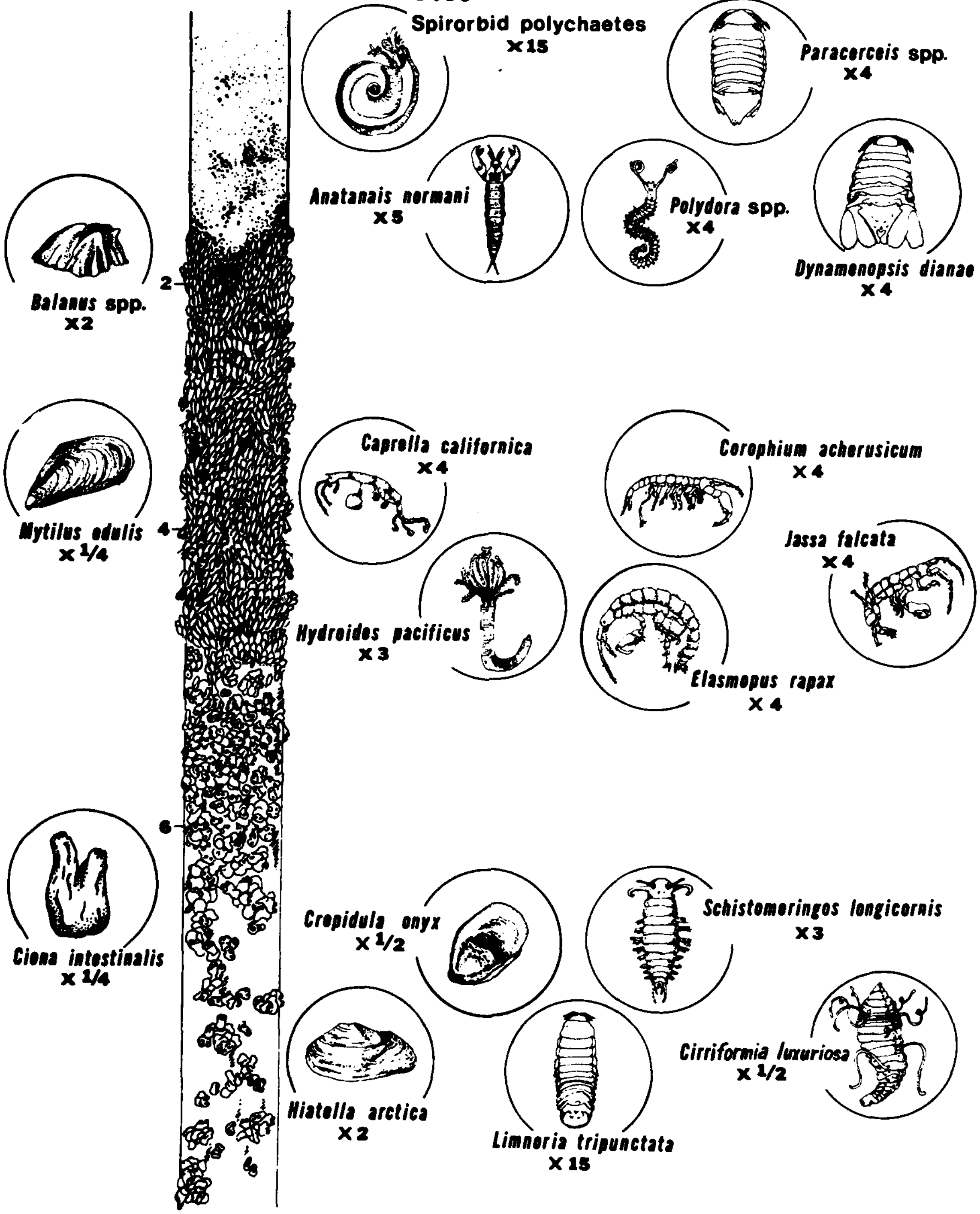
The classification of the Los Angeles-Long Beach Harbor study area produced similar site groups in respect to both the species number and abundance, for the four periods analyzed. The inner harbor stations located within the dead-end slips in the back reaches of the harbor consistently grouped similarly but at times included a dead-end slip nearer the outer harbor such as station A6 in Fish Harbor. The inner harbor stations grouped similarly irrespective of the variety of industrial and domestic waste discharges at each inner harbor station.

Stations located within the main channel around Terminal Island formed a similar group, while the outer harbor stations for the most part grouped similarly. It would be anticipated that the impact of the industrial and domestic waste discharges would be somewhat reduced, due to increased dilution and circulation at the channel and outer harbor stations. The basis for the site groups defined in the four study periods is herein suggested as responding to the impact of the various pollution sources on abiotic parameters such as temperature,

Table 5.16: Comparison of the Numerical Abundance Rank of Settling Rack and Piling Fauna.

Settling Rack Station C7	Piling Composite (6-station)
*Corophium acherusicum**	*Balanus* spp.
*Ciona intestinalis**	*Mytilus edulis*
*Polydora limnicola**	*Limnoria tripunctata**
*Hydroides pacificus**	*Elasmopus rapax**
Polydora ligni	*Polydora limnicola**
Capitella capitata	*Jassa falcata**
Ctenodrilus serratus	*Hydroides pacificus**
*Limnoria tripunctata**	*Corophium acherusicum**
*Balanus amphitrite**	*Ciona intestinalis**
Schistomeringos longicornis	*Caprella californica*
*Elasmopus rapax**	*Balanus amphitrite**
*Anatanais normani**	*Spirorbidae polychaeta*
Paleanotus bellis	*Anatanais normani**
Platynereis bicanaliculata	*Cirratulus cirratus*
*Jassa falcata**	*Paracerceis* spp.

* Indicates species which were common to both sampling methods.



DOMINANT SPECIES IN PILING COMMUNITIES BY DEPTH (in meters) Inner Los Angeles Harbor

Figure 5.21

dissolved oxygen, salinity and turbidity. Site groups, as defined by the species assemblages, are occurring in response to the abiotic parameters which are in turn directly influenced by the discharges.

The homogeneity of the station groups is especially surprising in the inner harbor dead-end slips, where limited water circulation and closer proximity to specific discharges might be expected to produce specific species assemblages within each discharge area.

Settlement activity of fouling organisms within the harbor area has a definite seasonal pattern which was evidenced in both the temporal and spatial aspects of this study. The summer period of June, July and August represents the period of maximum settlement activity in the harbor.

This is similar to the seasonal settlement of organisms associated with the settlement of the polychaetous annelid *Hydroides pacificus* (Reish, 1961) and the seasonal settlement of various other polychaetes in Los Angeles-Long Beach Harbors (Reish, 1971). This is also similar to the seasonal settlement of several amphipod fouling organisms (Barnard, 1958; Keith, 1971).

An exception to this general trend was the semiannual abundance of *Mytilus edulis*. Wolfson (1974) also found *Mytilus* to have a semiannual reproductive season in early spring and late summer-fall. All other exceptions to the general trend involved polychaetous annelids. Reish (1971) also found a spring and summer semiannual abundance of *Platynereis bicanaliculata,* but reported only a single population peak during the summer months. *Capitella capitata* was reported as having no seasonal peak, but reproduced continuously throughout the year except September through October. There was no seasonal peak for *Capitella* at those stations sampled in this study. Instead, there was evidence to support a yearly constant reproductive cycle. There were incidences where sudden declines and increases occurred sporadically but no cyclic pattern. Although *Polydora limnicola* shows an extended reproductive cycle, it is likely that this nears a continuous reproductive cycle. Grassle and Grassle (1974) believe that both *Polydora* and *Capitella* are opportunistic species with the ability to increase population size rapidly, generate maturation early and recede due to a high mortality rate, at stations which have low environmental predictability.

While the inner harbor, channel, and outer harbor site groups clustered similarly in all four survey periods, station B1 outside the breakwater did not consistently group with the outer harbor site group. During summer periods of 1973 and

1974 the settlement activity occurring outside the harbor at station B1 differed from the outer harbor. However, settlement activity at station B1 and the outer harbor site group was similar for both winter periods. The grouping of station B1 with the outer harbor site group during the winter periods may be a result of the limited settlement activity, which was insufficient to distinguish the outer and outside harbor sites. Alternatively, station B1 may be clustering with the outer harbor site group during the winter periods as a result of a greater water mass homogeneity between the outer and outside harbor. The increased circulation and exchange of water between the outside and outer harbor waters in response to increased surface wind activity (Robinson, pers. comm.) and the lower temperatures during the winter periods would reduce differences between the outer and outside harbor waters.

A quantitative survey of the polychaetes associated with the fouling organisms at monthly intervals for 17 months was conducted from 1966 to 1968 at five stations in Los Angeles Harbor (Crippen and Reish, 1969). The survey indicated a gradient of pollution from the outer to the inner harbor in respect to increasing discharge activity, decreasing dissolved oxygen, and salinity, and increased turbidity and temperature. A multivariate analysis of that data was not attempted. The earlier study considered the outer harbor near station A10 and the channel stations near C2 as "healthy" sites. The area near station C7 and C10 was characterized as "polluted", and station C10 was designated as "very polluted."

A pollution gradient in respect to the above parameters was also evidenced in the present study, grading from the outer to the inner harbor. Stations A10 and C2 both grouped with the channel stations in the present study, although they are not considered as representative of clean water or "healthy" sites since they did not group with the outer harbor stations. Unfortunately, the Crippen and Reish study did not cover any of the outer harbor stations included in the present study to offer comparison of the A10 and C2 stations in respect to the outer harbor. In any case, both studies suggest a relatively improved water quality at the outer harbor stations.

Each station in the Crippen and Reish study was characterized by at least one unique dominate polychaete in an attempt to evaluate the degree of pollution in terms of indicator organisms. The concept of indicator organisms has been attempted previously with the benthic polychaetes in the Los Angeles Harbor area (Reish, 1959). The most contaminated stations, C7 and C10, were characterized by *Schistomeringos*

longicornis (Stauronereis rudolphi) and *Polydora ligni*, respectively (Crippen and Reish, 1969).

In the present study these two species concentrated within the high stress environment of the inner harbor. The Environmental Stress Index (ESI) of *Schistomeringos longicornis* was 4.5 while *Polydora limnicola* was only 3.66, suggesting that *Schistomeringos longicornis* indicates an area of greater environmental stress than does *Polydora limnicola*.

Polychaetes which indicated the "healthy" channel and outer harbor stations in the Crippen and Reish study included *Ctenodrilus serratus* and *Halosydna johnsoni*. *Ctenodrilus serratus* was abundant, with an ESI of 4.0, suggesting it is more commonly found in the high stress environment of the main channel and inner harbor site groups. *Halosydna johnsoni* did not occur in sufficient abundance in the present study.

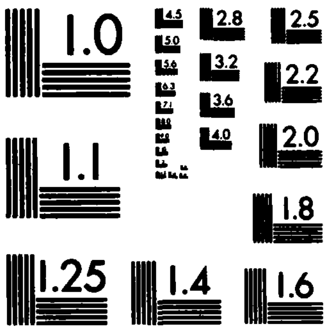
Non-polychaetes used to indicate healthy water conditions in the previous study included *Mytilus edulis* and *Hiatella arctica*; they were similarly classified in the present study, with Environmental Stress Indices of 2.25 and 1.0 respectively.

The benthic polychaete *Capitella capitata*, which is primarily found in fine sediments, occurs in abundance with fouling organisms and has been suggested by several investigators as an indicator of high levels of environmental contamination (Wilhelmi, 1916; Reish, 1959; Crippen and Reish, 1969). The use of *Capitella capitata* as a pollution indicator must be interpreted with caution. According to Bellan (1964), *Capitella capitata* prefers silty sediments and does not tolerate any fraction of coarse grain sediments. More recent evidence has shown that *Capitella capitata* is an opportunistic species which is one of the first species to recolonize an area that has been disturbed (Grassle and Grassle, 1974). It apparently does not compete well with more developed communities. These are important factors to consider in respect to recent and proposed dreding activities. The concept of pollution indicator organisms has been critically reviewed by Doudoroff and Warren (1957) in which they point out the necessity of specifying clearly what factors each indicator is presumed to indicate.

Previous studies of the Los Angeles-Long Beach Harbor area have generally been in agreement as to the nature or condition of the abiotic parameters on the harbor (Reish, 1959; Crippen and Reish, 1969; Barnard, 1958). Abiotic gradients in dissolved oxygen, temperature, turbidity and salinity exist in the harbor area. This general abiotic pattern of the

AD-A136 653 ENVIRONMENTAL INVESTIGATIONS AND ANALYSES FOR LOS ANGELES-LONG BEACH HARB..(U) UNIVERSITY OF SOUTHERN CALIFORNIA LOS ANGELES ALLAN HANCOCK F.. DEC 76 3/8

UNCLASSIFIED DACW09-73-C-0112 F/G 8/10 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

harbors and estuarine environments has also been reported in other harbor and estuary studies (Volk, 1907: Schlienz, 1923; Filice, 1959; McNulty, 1970).

The industrial and domestic discharges that occur in the harbor influence the abiotic parameters, which in turn determine the present species assemblages defined in this study. The major abiotic parameters which contribute to the environmental gradient within the study area were temperature and dissolved oxygen. Higher temperatures and lower dissolved oxygen levels contributing to the high stress environment within the inner harbor, are modified with the amount of incoming seawater from the outer and outside harbor areas. Secondary factors contributing to the abiotic gradient within the study area include turbidity and salinity. Higher temperatures and lower salinities in the inner harbor environment are ameliorated by increased circulation of the waters from the outer and outside harbor.

The inner reaches of the harbor undergo limited circulation which increases in the channel and outer harbor, respectively. Tidal effect on water movements have been simulated in a model of the study area by U.S. Army Corps of Engineers, Waterways Experiment Station. In addition, drogue studies and current meter measurements have confirmed the general circulation pattern in the study area (Soule and Oguri, 1972; Robinson and Porath, 1974). The outer harbor produces a major circulation gyre in response to the daily tidal flux. This influx of seawater from the outer harbor continues to provide a flushing effect. In addition, the harbor outer breakwater is a semipermeable structure which allows some exchange of water between the waters in the harbor and the outer environment (Lee and Walther, 1974).

Impact

The impact of the proposed dredging and filling within the study area represents two potential phases to consider in respect to the fouling organisms presently within the area: (1) The effect of increased dredging activities in respect to the proposed construction, and (2) the resulting long term effects upon completion of the proposed construction.

Heavy metals have been shown to concentrate in the bottom sediments and re-enter the water column as a result of dredging activities, thus increasing the toxicity potential of the water in respect to the fouling organisms (Chen and Lu, 1974; Emerson, 1974). Pesticides do not seriously affect water quality in respect to dredging, since most of the pesti-

cides remain in association with organic ligands and consequently resettle out of the water column with the organic particulates.

The most critical time to those fouling organisms within the study area is the summer period during which increased settlement activity occurs. The early development of marine organisms is considered as the most sensitive period in the life cycle (Bookout and Costlow, 1970; Hinu, 1965; Woelki, 1967). The early and larval stages of development would be the most susceptible to any increased water toxicity as a result of dredging operations during this period. The summer period is also a time of higher temperature and lower dissolved oxygen levels in the study area, which further increases the toxicity potential of these waters.

Proposed landfills, and the eventual reduction in the major central seawater gyre, will greatly reduce the amount of circulation occurring in the outer and inner harbor areas. A reduction in the influence of the outer harbor and seawaters with their higher dissolved oxygen and lower temperatures, will result in an abiotic shift in the channels and inner harbor. The presently defined high stress areas probably will be extended into the outer harbor in response to limited water circulation. The volume of water constituting the outer harbor will, under the final master construction plan, apparently be reduced more than 50%.

A reduction in the size of the outer harbor water mass reduces the dilution of contaminants concentrated in the inner harbor area. In this case the abiotic shift, as a result of limited circulation, is further suggested in respect to the reduced capacity of the harbor to dilute the input of contaminants. Present levels of discharge into the harbor would be diluted less rapidly as a result of the reduced water volume of the outer harbor.

The long term effects of the proposed construction would result in an abiotic shift within the harbor. The long term effect on the fouling organisms would range from reduced numbers of individuals and species to complete exclusion of the presently defined low stress species presently in the study area. A major shift in the biota would include an increase in the number of sites presently settled by those species herein considered as high stress and ubiquitous-high stress species. Ubiquitous species may not be able to continue successful settlement within some of the presently defined high stress environments of the study area.

LITERATURE CITED

Abbott, B. C., D. F. Soule, M. Oguri, and J. D. Soule. 1973. In situ studies of the interface of natural and man-made systems in a metropolitan harbor. Helgoländer wiss. Meeresunters. 24:455-464.

Barnard, J. L. 1958. Amphipod crustaceans as fouling organisms in Los Angeles-Long Beach Harbors, with reference to the influence of seawater turbidity. Calif. Fish and Game. 44(2):161-170.

Barnard, J. L., and D. J. Reish. 1959. Ecology of Amphipoda and Polychaeta of Newport Bay, California. Allan Hancock Publications. Occasional Paper No. 21. pp. 1-106.

Bookhout, C. G., and J. D. Costlow, Jr. 1970. Nutritional effects of *Artemia* from different locations on larval development of crabs. Helgoländer wiss. Meeresunters. 20:435-442.

Chen, K. Y., and J. C. S. Lu. 1974. Sediment compositions in Los Angeles-Long Beach Harbors and San Pedro Basin. In Marine Studies of San Pedro Bay, California. Part 7. Allan Hancock Foundation and Sea Grant Program, University of Southern California. 177 p.

Crippen, R. W., and D. J. Reish. 1969. An ecological study of the polychaetous annelids associated with fouling material in Los Angeles Harbor with special reference to pollution. Bull. So. Calif. Acad. Sci. 68(3):170-187.

Davis, J. C. 1973. Statistics and data analysis in geology. John Wiley and Sons, Inc. 550 p.

Doudoroff, P., and C. E. Warren. 1957. Biological indices of water pollution. In Biological Problems in Water Pollution. Cincinnati, U. S. Public Health Service. pp. 144-163.

Emerson, R. 1974. Effects of resuspended sediment on two species of benthic polychaetes from Los Angeles Harbor. In Marine Studies of San Pedro Bay, California. Part 3. Allan Hancock Foundation and Sea Grant Program, University of Southern California. 14 p.

Felice, F. P. 1959. The effects of wastes on the distribution of bottom invertebrates in the San Francisco Bay estuary. Wasmann J. Biol. 17(1):1-17.

Grassle, J. F., and J. P. Grassle. 1974. Opportunistic life histories and genetic systems in marine benthic polychaetes. J. Mar. Res. 253-284.

Hinu, H. 1965. Effects of synthetic surfactants on the larvae of clams (*M. Mercenaria*) and oysters (*C. virginica*). J. Wat. Pollut. Control. Fedn. 37:262-270.

Keith, D. E. 1971. Substrate selection in caprellid amphipods of southern California, with emphasis on *Caprella californica* Stimpson and *Caprella equilibra* Say (Amphipoda). Pacific Science. 25:387-394.

Lee, J. J., and A. Walther. 1974. Wave energy permeation of San Pedro breakwater. Sixth Annual Offshore Technol. Conf., Paper No. 2124. Houston, Texas. 951-958.

McNulty, J. K. 1970. Effects of abatement of domestic sewage pollution on the benthos, volumes of zooplankton, and the fouling organisms of Biscayne Bay, Florida. Stud. Trop. Oceanogr. Miami 9: 107 pp. 19 figs.

Perkins, E. J. 1974. The biology of estuaries and coastal waters. Academic Press. 678 p.

Reish, D. J. 1961. The relationship of temperature and dissolved oxygen to the seasonal settlement of the polychaetous annelid *Hydroides norvegica* (Gunnerus). Bull. So. Calif. Acad. Sci. 60(1):1-11.

Reish, D. J. 1971. Seasonal settlement of polychaetous annelids on test panels in Los Angeles-Long Beach Harbors 1950-1951. J. Fish. Res. Bd. Can. 28:1459-1467.

Robinson, K., and H. Porath. 1974. Current measurements in the outer Los Angeles Harbor. Marine Studies of San Pedro Bay, California. Part 6. Allan Hancock Foundation and Sea Grant Program, University of Southern California. 91 pp.

Schlienz, W. 1923. Verbreitung und Verbreitungsbedingungen der höheren Krebse im Mundungsgebiet der Elbe. Arch. Hydrobiol. 14:429-452.

Soule, D., and M. Oguri. 1972. Circulation patterns in Los Angeles-Long Beach Harbor. Marine Studies of San Pedro Bay. Part 1. Allan Hancock Foundation and Sea Grant Program, University of Southern California. 113 p.

Soule, D. F., and J. D. Soule. 1971. Preliminary report on techniques for marine monitoring systems. Sea Grant Tech. Note (USC-SG-IT-71), University of Southern California. p. 1-5.

Volk, R. 1907. Mitteilung über die biologische Elbe-Untersuchung des Naturhistorischen Museums in Hamburg. Verh. naturw. Ver. Hamb. 15:1-54.

Woelke, C. E. 1967. Measurement of water quality criteria with the Pacific oyster bioassay. Water Quality Criteria, ASTM Spec. Tech. Pub., Am. Soc. Test. Mater. p. 112-120.

Wolfson, A. A. 1974. Some effects of increased temperature on the settlement and development of a marine community in the laboratory. Univ. of California Institute of Marine Resources. UC-IMR Ref. 74-13. Sea Grant Publ. 39. 83 p.

Chapter 6

BENTHIC ECOLOGY

6.1

BENTHIC ECOLOGY

INTRODUCTION

The first major, and until now the most comprehensive, study of the marine benthic ecology of Los Angeles-Long Beach Harbors was conducted in the early 1950's (Reish, 1959). Reish found that some portions of the harbor benthos (sediments covered by salt water) were devoid of macroscopic animal life; because of the high organic load, the low dissolved oxygen (DO) and the presence of hydrogen sulfide (H_2S) these areas were characterized as very polluted. Areas that were less polluted supported more diverse assemblages of benthic species.

More recently, many less comprehensive surveys have been conducted in the harbor for private industry. The results of these studies, if compared to Reish's original work, suggest a general improvement of benthic conditions, with more species and less pollution in some areas. Such improvement would have probably resulted from pollution abatement measures enacted in 1968-1969 (Reish, 1971), although differences in sampling techniques do not permit exact comparison.

Since 1971 Harbor Environmental Projects (HEP) of the Allan Hancock Foundation, University of Southern California, has maintained an extensive monitoring program and conducted numerous small-scale studies in the harbor complex. In 1972 HEP entered into contract with the Army Corps of Engineers to assess the biota and environment of the harbor and, on the basis of those findings, to predict the effect on the ecosystem of proposed dredge-and-landfill operations in the outer harbor.

Consideration of the benthos is especially appropriate when dredge-and-fill operations are anticipated. First, it is benthos itself which is most directly affected by the removal of sediments in some places and deposition in others. Second, many pollutants tend to accumulate on or in the surficial sediments, either because they are heavier than water or because they adsorb onto particles that are heavier. Finally, the organisms which inhabit the benthos are generally immobile; if an area is adversely affected, such organisms cannot move to a more suitable environment, and they die or cease reproducing. It follows that the community structure among benthic organisms reflects conditions which have prevailed at a given site for some time before actual sampling. By contrast, physico-chemical measurements of the water column or samples of the organisms which inhabit it only indicate conditions at the time of sampling. These conditions - biotic and abiotic - may vary as regularly as the tides or as irregularly as local storms.

METHODS AND MATERIALS

The location and designation of the 34 benthic stations under consideration are indicated in Figure 6.1 . Although many of these stations have been sampled regularly from late 1972 to February 1975, this report deals with single biological samples obtained at each station in March, August, and November, 1973 and February, 1974 (one full year).

Samples of the sediments were obtained from the R. V. Velero IV with a box (=spade) corer. This device samples 1/16 m^2 to a depth of at least 30 cm. in the harbor sediments. On board a 100 cc sub-sample was removed and frozen for grain-size and chemical analysis. Samples were then washed through screens with openings of 0.5 mm; material retained on the screen was fixed immediately in 10% buffered formalin-seawater and transferred within 48 hours to 70% isopropyl alcohol for preservation. Sorting of infaunal organisms from debris was accomplished with at least 5X magnification; all organisms except copepods, nematodes and ostracods were identified to the lowest possible taxon and counted.

Four additional biotic measures were obtained from other sections of the study and are included as extrinsic factors in this section. These are: plankton settling density, productivity, chlorophyll *a* and assimilation ratio.

Physical/Chemical

Measurements of DO, salinity, pH, temperature and turbidity (transmissivity) to depths within 1 meter of the bottom were taken monthly over the two-year period of the study with Martek remote sensors.

Grain size analysis of the sediment was by accepted geological methodology; the pipette method for silt and sand fractions and settling-tube for sand and gravel.

Analyses for chemical parameters of the sediments were performed in the laboratories of K. Chen, Environmental Engineering, U.S.C. The methods used are summarized in Smith (1973) and detailed in Chen and Lu (1974).

Observations on currents and circulation were derived from photographs taken of the Army Corps model of Los Angeles-Long Beach Harbors at the Waterways Experiment Station, from previous Harbor Environmental Project drogue studies (Soule and Oguri, 1972) and current meter measurements (Robinson and Porath, 1974).

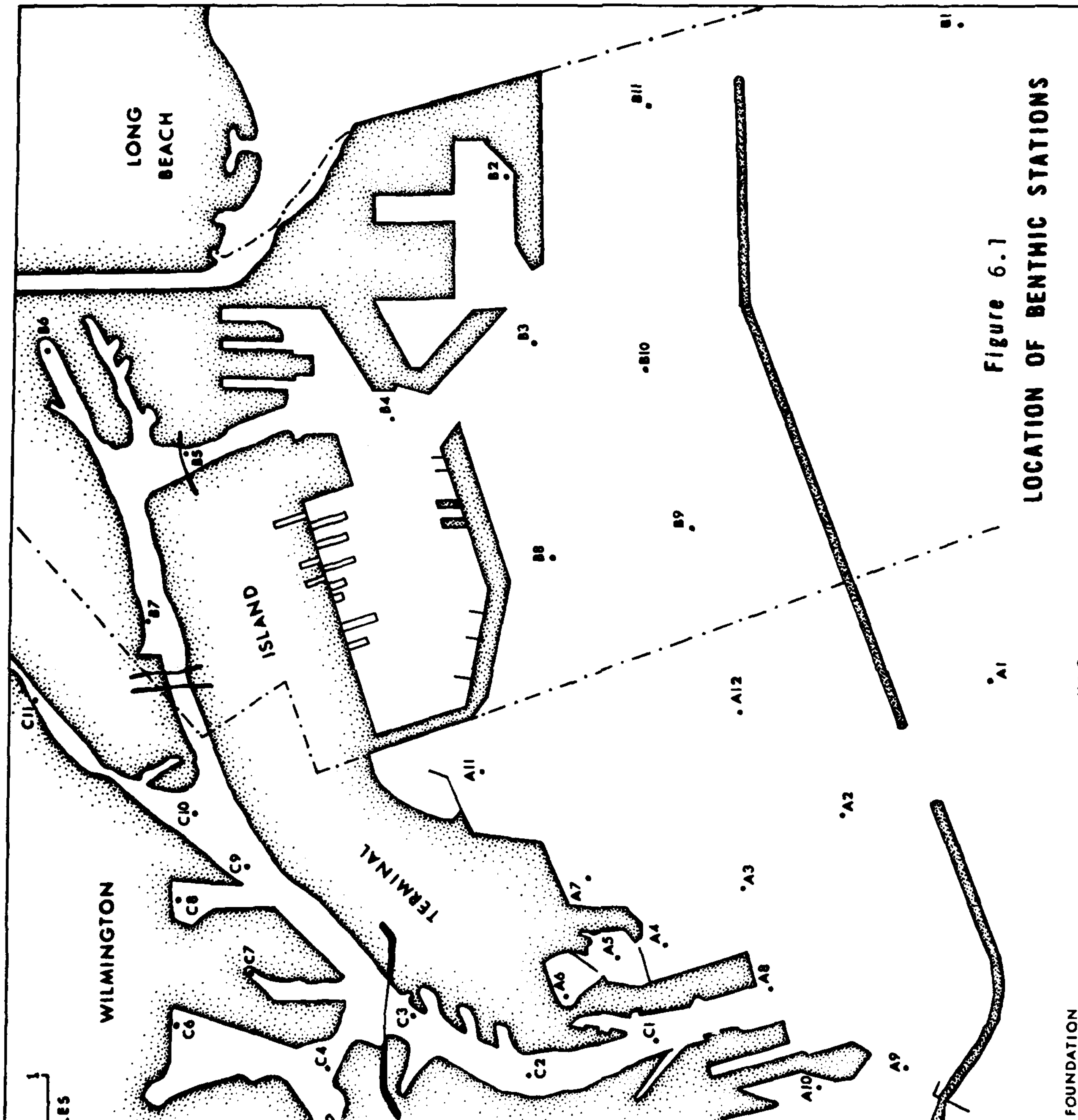


Figure 6.1
LOCATION OF BENTHIC STATIONS

Data Analysis

The overall analytical plan is summarized as follows:

1) Description of the existing biota, emphasizing similarities among the 34 stations using classification analysis.

2) The use of discriminate analysis to find the correlations of biotic assemblages with distinctive abiotic conditions in an effort to understand the causes for differences in the biota.

Analytical methodology is discussed in Chapter 2, in detail. Because such a large amount of information was collected, only summarized data are presented in the report proper. Complete raw data, biotic and abiotic, are available from the Harbor Project in the form of computer print-outs or computer tape retrieval.

RESULTS

Benthos

Over 180,000 individual organisms were counted from the 129 benthic samples considered; these included 20 monospecific taxa, plus numerous polyspecific groups, in 10 invertebrate phyla.

Averages of 28 species and 1404 individuals were found in each sample, but variation was high. Thus, the number of species ranged from 1 to 60 per sample and the number of individuals from 2 to over 5,000 (80,000/m^2).

Within the taxa identified to species level, 140 were polychaetous annelids and 48 were molluscan species. In the number of individuals collected, the Polychaeta was also the most abundant group. The polychaete *Tharyx ? parvus* alone accounted for 45% of all benthic organisms identified to species level and the 10 most abundant species, all of which were polychaetous annelids, accounted for 90% of the individuals collected (see Table 6.1).

Normal Classification

The 72 infaunal species most commonly encountered in the present study were used in classification. Initially, the 129 samples were classified individually, without regard to when or where they were collected. This produced a dendrogram with five clear station groups; importantly, the groups were based on spatial, not temporal, differences in the stations. That is, samples from the same station (though taken at different times of the year) tended strongly to cluster together. An alternative result would have been the generation of four groups, each

Table 6.1 . The Ten Numerically Dominant Species from the Los Angeles-Long Beach Harbors Benthos, 1973-74.

	Species	Number Collected	Percent of Total	Cumulative Percent
1	*Tharyx ? parvus*	74,763	45.11	45.11
2	*Capitata ambiseta*	24,640	14.87	59.98
3	*Cossura candida*	22,278	13.44	73.42
4	*Capitella capitata*	9,450	5.70	79.12
5	*Paraonis g. oculata*	4,352	2.63	81.75
6	*Euchone limnicola*	4,187	2.53	84.28
7	*Chaetozone corona*	3,510	2.19	86.40
8	*Sigambra tentaculata*	2,392	1.44	87.84
9	*Prionospio cirrifera*	2,232	1.35	89.19
10	*Schistomeringos longicornis*	2,100	1.27	90.46

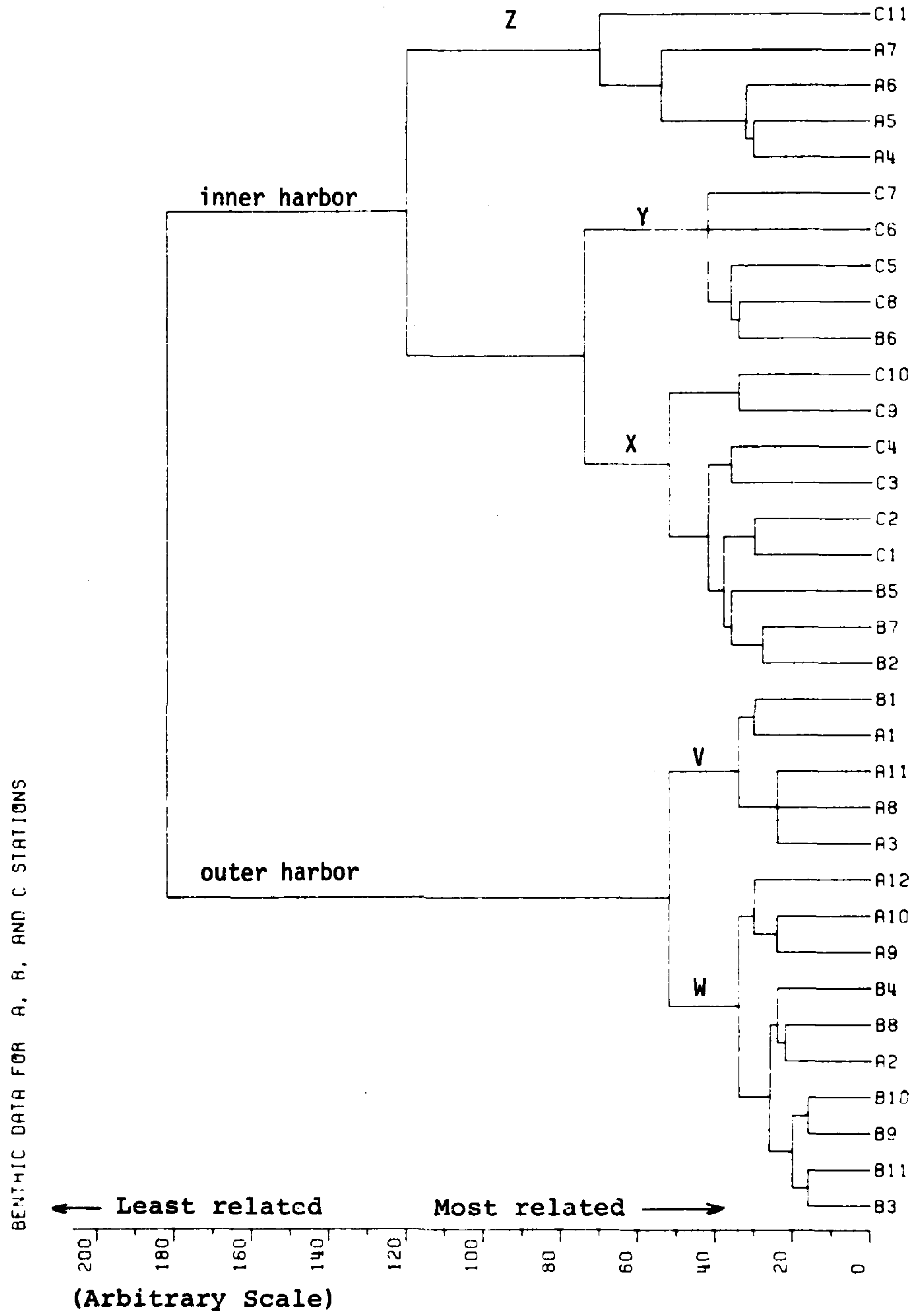
containing samples taken on the same date. Because stations grouped by space rather than time it was concluded that benthic variation in the harbor is greater from place to place than from season to season.

To substantiate this observation, the group of samples taken on a single date was classified separately and the resulting station groups compared for evidence of drastically different sorting at different times. None was found; only a few stations shifted from group to group. Therefore, the averaging of samples obtained at each station on different dates was felt justified, in order to produce the simplest possible picture of the harbor assemblages (for precedent, see Day, et al., 1971). The normal dendrogram which resulted from the classification of averaged data is presented in Figure 6.2 .

Decision on where to break the dendrogram into different groups is arbitrary; at the one extreme one would have as many groups as stations, at the other there would be just one. Obviously neither extreme helps to define the biotic regions of the harbor.

The first major split in the present case produced two major groups of stations and scrutiny of these revealed that the stations in the one group are from inner harbor (in and about

Figure 6.2
CLASSIFICATION OF BENTHIC STATIONS



channels) and the others from outer harbor (within and outside the breakwater). (Figure 6.3).

Both of these station groups can be broken down further, as they have been at the right of Figure 6.2. These groups are indicated in their actual position in the harbor in Figure 6.3. On the basis of their location with respect to major harbor features, these five groups appear to characterize the following parts of the harbor:

GROUP V: Outside breakwater and inner portion of outer harbor.
GROUP W: The major portion of outer harbor.
GROUP X: The main channels.
GROUP Y: Dead-end channels, slips and basins.
GROUP Z: Fish Harbor and Dominguez Channel.

As befits the methods of classification, these groups are viewed as discrete units which are relatively homogeneous within groups but heterogeneous among groups. It should also be noted that the stations which comprise each group are not necessarily contiguous in space, but may be widely separated. This is a result of the fact that the grouping is based on faunal similarities, not topographic or physico-chemical factors. Thus, station B6 is well separated from the others in Group Y, implying nonetheless a very similar fauna. In this case it is obvious that these stations also share a common topographic feature: they are all located in dead-end channels and as such might be expected to support a very similar fauna.

<u>Inverse Classification</u>

Just as stations can be classified on the basis of the kinds and number of species present, so the animals can be classified on the basis of their distribution and abundance at the various stations. This inverse analysis results in a dendrogram of species, i.e., species with similar patterns of distribution and abundance form groups.

Since significant temporal changes were not found in the normal analysis patterns, preliminary inverse classifications were not done; the analysis was conducted on the same averaged data as the final normal analysis. The resulting dendrogram is presented as Figure 6.4. Examination of this figure indicates a major split into two large species groups.

Within the two main groups, sub-division into smaller groups was more difficult than in the normal dendrogram. This is because a certain amount of chaining developed. Chaining is a phenomenon in which species (or sites) are added singly to a larger group, producing a dendrogram which resembles a staircase. This suggests a continuum of species distribution rather than discrete groups. Eight species groups were selected, how-

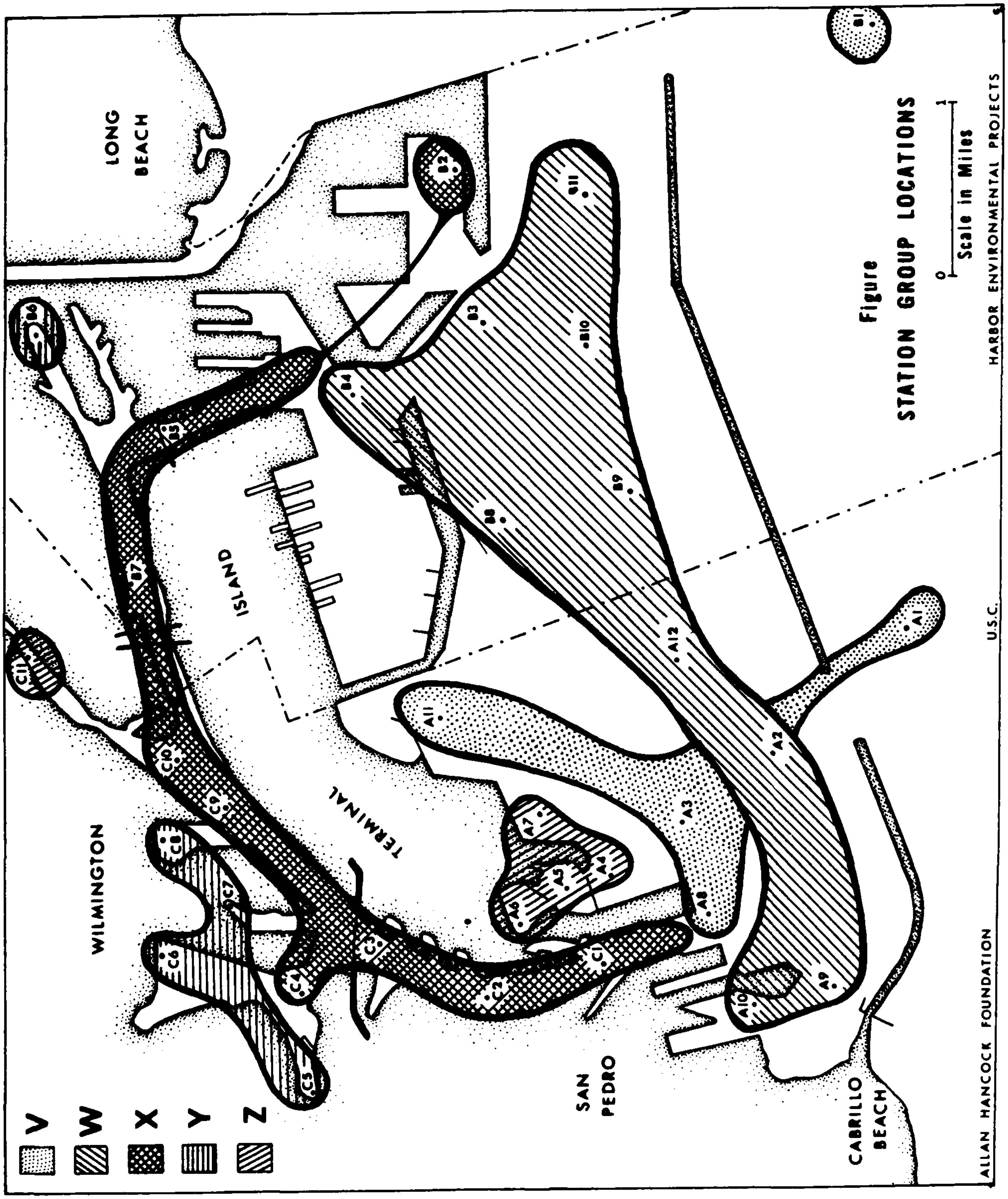

V
W
X
Y
Z
LONG BEACH
WILMINGTON
ISLAND
TERMINAL
SAN PEDRO
CABRILLO BEACH
U.S.C.
Figure
STATION GROUP LOCATIONS
0
1
Scale in Miles
HARBOR ENVIRONMENTAL PROJECTS
ALLAN HANCOCK FOUNDATION

Figure 6.3

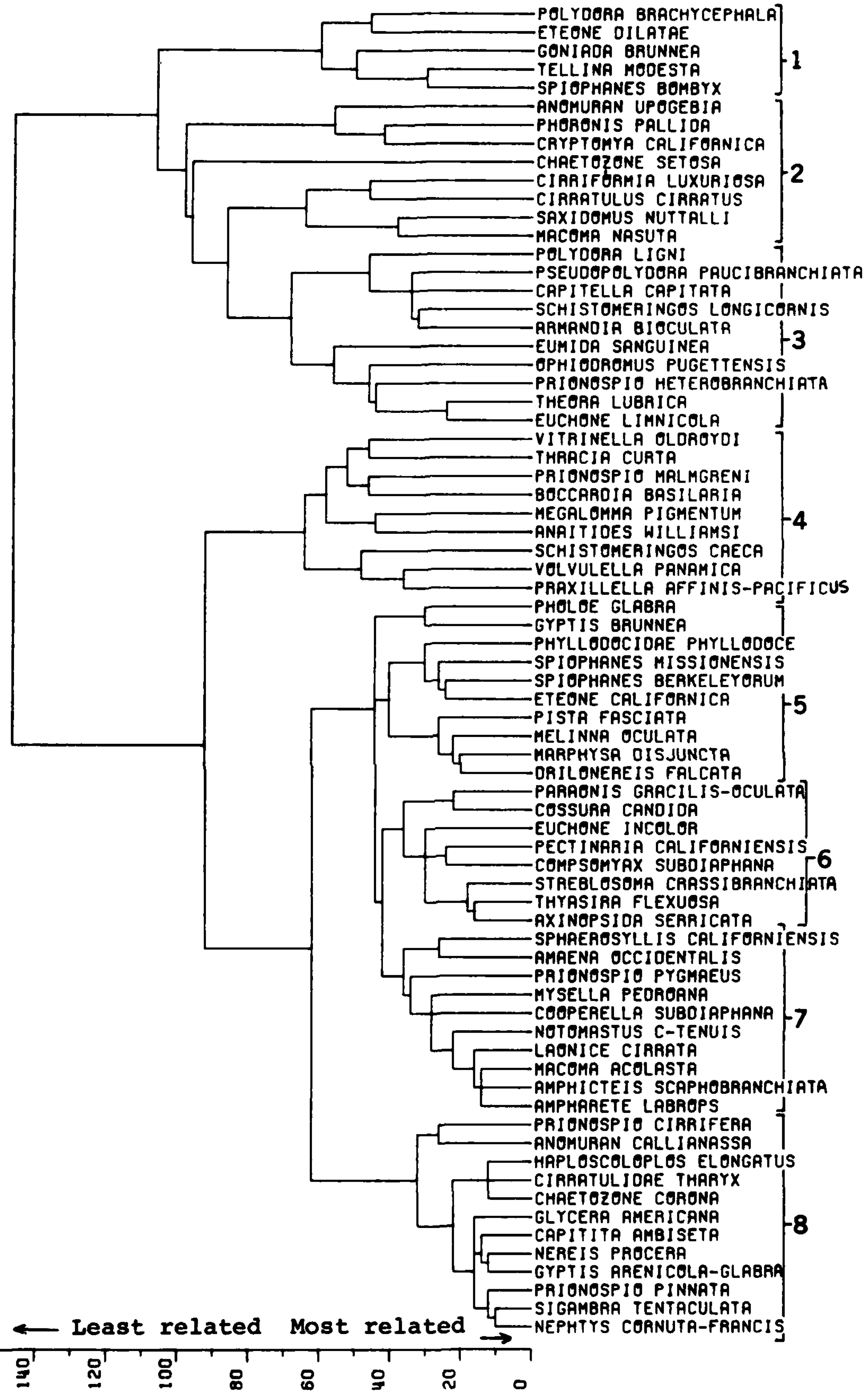


Figure 6.4
INVERSE ANALYSIS OF SPECIES GROUPS
BENTHIC DATA FOR A, B, AND C STATIONS

ever, as indicated at the right of Figure 6.4 .

Two-way Tables

The normal and inverse dendrograms can be used to construct a two-way table (TWT). The TWT is nothing more than the original data matrix with the rows (of species) and columns (of stations) arranged in the same order as in their respective dendrograms. This creates a matrix of cells, formed by the interception of species- and station-group divisions. If particular species, or groups of species, are especially abundant in a particular cell, the species may prove to be characteristic of that particular station-group. The actual table with 73 species and 34 stations was generated, but is large and unwieldy. Table 6.2 presents the equivalent, in which symbols indicating the transformed abundance of each species, relative to its own mean, are entered at each station rather than actual numbers.

Interpretation is best illustrated with examples. In Table 6.2, station group Z is easily characterized by several species in species group V , which were most abundant (see box); most species in all other groups are relatively rare or totally absent in stations of group Z. Conversely, species group I is distributed widely over the five station groups, but is relatively more abundant at W than V, V than X, and so forth.

Unfortunately, little is known concerning the biology of most of these species. With more information on physiology, feeding, reproductive type and time, plus predatory and competitive interactions, it might be possible to identify important biological patterns within and among groups.

Extrinsic Factors

Complete extrinsic factors such as abiotic measures of the sediments and water column and the four biotic measures of the water column were available for 27 of the 34 sampling sites. Data were incomplete from stations A7, A11, B4, B7 B9, B10 and B11, and were so deleted.

Sediment chemicals were determined during November and December, 1973 and averaged; grain size data utilized was from November, 1973 only; and the other parameters were measured monthly and averaged for use in the following analyses. Extrapolation from one sample to the year's data for sediment chemistry and grain size is justifiable since these parameters are less subject to short-term change than those of the water column, although they are variable.

Detailed information on the patterns of currents, water movements and general exchange within the Los Angeles-

Table 6.2

SPECIES	SPECIES GROUP	STATION GROUPS V	W	X	Y	Z
N. c. franciscana		+ + + + -	+ + + - + - - . . -	+ + + + + - - + -	. - . - -	.
S. tentaculata		+ + + + +	+ + - - + - - - - +	+ + + + - - - - -	- - - - .	. .
P. pinnata		+ + + + -	+ + + + + - - - - +	+ - + + - - - - -	- - - -	-
G. a. glabra		- + + + +	+ + + + - + - - + +	+ + + - - - - -	- - - -	
N. procera		+ + + + +	- + - + + + + - + +	- - + + - - - - -	- . - - -	.
C. ambiseta		- - + + +	+ + + - + + + - - +	- + + + + + - - -	. - - - -	. . -
G. americana	I	+ - + + -	+ + - + + + - + - +	- - + - - - + -	- -	
C. corona		+ - + + -	+ + * + + - - - - -	+ - + + + - - . .	. . . .	.
Tharyx sp.		+ + + * +	+ + + + + - + - - -	+ + + + + - - - -	. . . - .	. . . .
N. elongatus		+ + + + +	+ + + + + - + - - -	- - + + -	.	. .
Callianassa sp.		+ - + + -	- + - - + - - - + +	+ + + + + + + - -	- - + -	- + -
P. cirrifera		- - - + -	- - + - - + * + - +	- - + + + + - . .	- . .	. . . *
A. labrops		- - + + +	- + - - - - + + + +	- - -	-	
A. scaphobranchiata		- + + + +	- + - - + + + + - +	. + -		
N. acolasta		- + + + +	- - + + + + + +	- - - - -		
L. cirrata		+ - + + -	+ + + + + - - + - +	- - - - -	-	
N. ctenuis		+ - - + +	- + - . - + + + + +	. - - - +		
C. subdiaphana		. - - . +	+ + + + + + - - +	- - -		
N. pedroana		- - - + +	- - - - - + -	-		
P. pygmaeus		- - -	+ - - - + - + + + *	- - - - - - - -		
A. occidentalis	II	- - + + -	+ + + + - +	- - - -		
S. califorriensis		- - + - +	+ + + - + + -	- -		
A. serricata		+ + + + -	+ + + + + - - - +	- - - - - -	-	
T. flexuosa		+ + + + +	+ + + - + - - -	- - - - -	-	
S. crassibranchiata		+ + + + +	+ + - + + - - . -	- - -		
C. subdiaphana		+ + + + +	+ - - - - -	- + - - - -		
P. californiensis		+ + + + +	- - - - - - + + -	- - - -	-	-
E. incolor		+ + + * -	+ - . . + . . - - *	- . . -		
C. candida		+ + + + +	* + + + + - * + . .	+ . . * + - . . .	. . .	. . .
P. g. oculata		+ + + + +	+ - + + + . - . . -	. + . .		. .
D. falcata		+ + + + +	- - - - - - -	-		
N. disjuncta		- + + + +	+ + - - + - - - -	- -		
N. oculata		+ + - + +	- + - - - - - +	+ - -		
P. fasciata		- + - + +	- - - - - + - +	-		
E. californica		- + + + +	- + - - - - +	+ - + - - -		
S. berkeleyorum		- + + + +	+ + . - + - . - - +	+ + - . - -	- .	
S. missionensis		+ + + + -	- + - + - - - + - +	- + - - - + - +	+ + +	-
Phyllodoce sp.		+ + + + -	- + + - - + +	- - - -	-	
G. brunnea		- + + -	- + + + - - - -	+ - + + - - -		-
P. glabra		- + + + -	+ - - - + - -	- -		-
P. a. pacificus		+ - + -	+ + - -		-	
V. panamica		- + + +	- - - - -			
S. caeca		- + +	- * - -	+ + + -	- - - -	
A. williamsi		- - +	- + - -	- +		
N. pigmentum		- + +	- + + + -	- - - +		
B. basilaria	III	- - *	+ - - + - - -	-		
P. malmgreni		+ + +	+ - - - - * +	- + - +	-	
T. curta		- - - + +	+ - -	-		
V. ordroydi		- + + * +	- - -	- - - - +		
E. limnicola		- . - .	- - + * - . - -	- + + + + + + + +	- - - + -	.
T. lubrica		- - - -	- - - - - - - -	+ - + - - + - + +	+ - + +	
P. heterobranchiata	IV		- - + - -	+ + + - - + -	- - +	-
O. pugettensis		+ + - + -	- - - + - +	+ - - -	+ - + - +	+
E. sanguinea		- -	- + + - + -	+ - +	+ +	+ -
A. bioculata		-	- - + - * + + - -	- . + - . + .	- . . * +	+ + - * .
S. longicornis		- . -	+ - - + + - .	+ . + + . - - - -	* + + + +	+ + - - +
C. capitata	V	. .	. . . + + - - .	. . . . - . .	* + - - +	* * * * *
P. paucibranchiata		-	- - - + - - + - -	+ - - + - + -	* - - +	+ * + -
P. ligni		.	.	- . - - .	- . - - +	+ * * +
N. nasuta		- - -	- - + + +	- - + +	- - +	
S. nuttalli		+	- - + + -	+ + - - -		-
C. cirratus	VI		- +	+ + + +	- - -	
C. luxuriosa		-	+	+ -	- - + - +	
C. setosa			- +	.	+ +	
C. californica		- .	.	+ + * - - + + -	-	
P. pallida	VII	- +	-	+ - - + + + -	-	
Upogebia sp		-	-	- - + +	- -	
S. bombyx		- -	- - + + +	-		
T. modesta		- -	- + + + + + +	- -		
G. brunnea	VIII	- + -	- + + +	+		
E. dilatae			- + - + + +	- - + -		
P. brachycephala		- -	+ - + + - +	- - + - - + +	- -	+

Table 6.3. Characteristic Species of the Five Station Groups. Los Angeles-Long Beach Harbor, 1973-1974.

Station Group	Species
V	*Macoma acolasta* *Notomastus tenuis* *Prionospio pygmaeus* *Tellina modesta*
W	*Tharyx ? parvus* *Cossura candida* *Haploscoloplos elongatus* *Prionospio pinnata*
X	*Euchone limnicola* *Callianassa* *Cryptomya californica* *Nephtys c. franciscana*
Y	*Schistomeringos longicornis* *Capitella capitata* *Ophiodromus pugettensis* *Theora lubrica*
Z	*Capitella capitata* *Armandia bioculata* *Polydora ligni* *Pseudopolydora paucibranchiata*

Long Beach Harbor complex is unfortunately scant. However, generalizations are apparent from the several sources mentioned earlier; these have the advantage that they verify the investigators intuitive feelings about water movement within the harbor complex.

These observations are easily summarized. 1) There is a large surface gyre in the outer Los Angeles Harbor, and 2) water movement decreases as one moves further into the harbor into channels, side channels and dead-end channels.

The average raw values by station group are presented in Table 6.4. Depth increased from Z to V station-groups. The sediments were generally finest in groups Y and Z and coarsest in groups V and X. Virtually all pollutants including 9 heavy metals, DDT, PCB, oil and grease, were highest in station group Y, in dead-end channels, and lowest in outer stations, group V and W. Chemical oxygen demand (COD) and total organic carbon were highest in group Z at Fish Harbor and Dominguez Channel, and lowest in the outer harbor group V.

Table 6.4. Raw Extrinsic Data, Summarized as the Means Within Each Station Group.

EXTRINSIC FACTOR *log transformed	STATION GROUP V	W	X	Y	Z
Depth (m)*	13.7	12.4	11.8	9.8	6.6
Sediment Diversity*	2.5	2.20	2.50	2.36	2.35
Mean Phi*	3.9	5.0	4.4	5.7	6.0
Skewness	2.0	1.0	1.5	0.4	0.1
Percent Sand	80.0	22.6	64.0	17.0	27.0
Percent Silt	15.0	45.0	28.0	34.0	55.0
Percent Clay	5.0	42.0	8.0	50.0	18.0
Sorting	15.0	13.0	16.3	16.0	16.5
COD (ppm X 10^2)*	259	466	462	561	750
Total Org. Carb. (ppm)*	0.86	1.34	1.20	1.49	1.83
Total Volat. Solids (ppm)*	3.85	6.05	4.38	6.72	6.43
Immed. Oxyg. Demand (ppm)*	374	618	664	1252	1194
Oil & Grease (ppm)*	733	1235	229	3494	2616
Kjeldahl N (ppm)*	173	666	438	678	635
Organic Nitrogen*	167.4	323.0	398.8	1889.4	595.8
Phosphorus	896	1432	1305	147.1	1482
Sulfide*	135	296	417	1248	1128
Mercury (ppm)*	0.40	0.5	0.86	2.05	1.36
Lead (ppm)	75	100	102	141	206
Zinc (ppm)	96	171	160	293	432
Arsenic (ppm)	6.5	6.9	10.7	12.8	8.8
Cadmium (ppm)	2.3	3.6	3.5	5.0	4.2
Nickel (ppm)	30.0	48.0	42.0	58.0	45.0
Copper (ppm)	81.0	151.0	81.0	213.0	199.0
Iron (ppm X 10^2)	209	364	265	305	284
Chromium (ppm)	38.7	83.7	86.1	188.8	126.7
Total DDT*	0.40	0.704	0.38	0.59	0.97
Total PCB*	0.45	0.59	0.71	1.45	1.53
Mean Plank. Sett. Dens.	0.86	0.54	0.89	0.85	0.65
Mean Productivity	42	45	58	74	63
Mean Chl. a	2.5	4.4	5.4	6.3	3.9
Mean Assim. Ratio	7.29	6.58	8.69	8.57	8.55
Mean Temperature (°C)*	14.7	15.1	15.4	16.5	16.6
Std. Dev. Temp. (°C)*	0.86	0.8	0.72	0.55	0.68
Mean Salinity (°/oo)	33.44	33.55	33.57	33.55	33.46
Mean Diss. Oxygen (ppm)*	6.2	5.6	5.2	4.5	4.4
Min. Diss. Oxygen (ppm)*	5.0	3.9	4.5	3.5	2.8
Mean Transmission*	0.71	0.69	0.63	0.63	0.67

Discriminate Analysis on Extrinsic Factors

If one has, *a priori*, groups of entities and measures several variables on each entity, discriminant analysis can be used to determine which variables contribute most to the separ-

ation into groups. In the present application, the station groups established by classification were the *a priori* groups necessary; the variables measured were the 38 extrinsic factors associated with each station.

In a discriminant analysis, the number of variables (38 measured) cannot exceed the number of sites considered (27 in this case). Therefore, 11 extrinsic were eliminated, based upon their correlation with other factors and the likelihood of their having an effect on the biota.

Some of the 21 remaining factors (marked with an asterisk in Table 6.4) were log transformed before analysis to make their distributions more normal. The first two discriminant axes appeared sufficient to separate the groups delimited. The stations are located by groups in this two-dimensional, extrinsic factor space in Figure 6.5 . The coefficients of separate determination, which indicate the relative importance of the various extrinsic variables in the separation of the groups are shown in Table 6.5 .

By perpendicular projection into the first axis, station groups V, Y and Z are completely separated. Although groups W and X overlap on the first axis, they are well separated on the second.

As indicated in Table 6.5 , the first axis is primarily a function of mean DO, and minimum DO, (which increase toward the V group) and secondarily related to Hg, sulfide, temperature and IOD, which increase toward the Y group. The second axis, which separates X from the other group is primarily a function of turbidity (it being greater in group X than in all others); oil and grease are also higher in group X while DDT is lower in the X group of channel stations.

DISCUSSION

For purposes of discussion, the five station groups delimited by classification and used subsequently in other analyses may be reduced to three: 1) V and W combined as 'outer' stations; 2) Group X, the 'channel' stations; and 3) Groups Y and Z combined as 'inner' stations. This regrouping is consistent with the averaged data dendrogram (Figure 6.2) used to delimit the five original groups, but amounts to establishing groups at a lower level of similarity.

The analyses performed produced a general picture in which the infaunal community closely reflects the abiotic conditions at each site or in each site group. The outer stations support a relatively diverse and abundant infaunal community; abiotically, these stations are characterized by higher levels of dissolved oxygen and relatively low levels of a host of pollutants - heavy metals, DDT, PCB - and indicators of a low oxygen environment, sulfide and IOD.

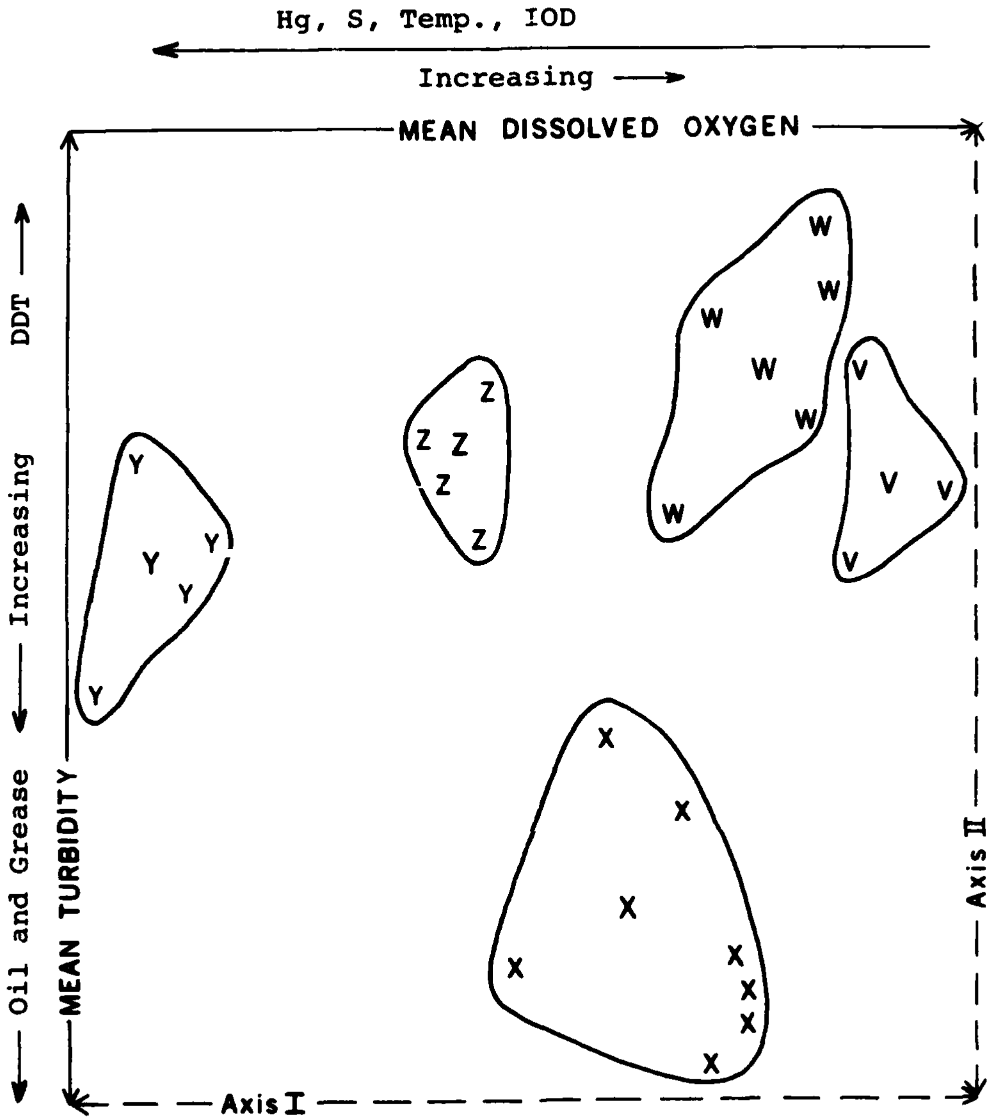


Figure 6.5

Location of Stations and Station Groups in the Two-dimensional Abiotic Space Defined by the First Two Discriminant Analysis Axes. The main variable associated with each axis is noted.

Table 6.5. Coefficients of Separate Determination from the Discriminant Analysis of the Station Groups.

VARIABLE	Axis I	Axis II
Sediment Diversity	0.05	0.72
Depth	1.87	0.10
Mean Phi	0.79	0.36
COD	1.96	0.26
TOC	0.19	0.003
IOD	2.37	0.06
Oil and Grease	0.50	0.84
Organic N	1.96	0.14
Sulfide	2.98	0.25
Hg	4.02	0.18
Total DDT	0.98	0.84
Total PCB	1.22	0.04
Mean Temperature (^{o}C)	2.72	0.02
Stand. Dev. Temperature (^{o}C)	0.01	0.06
Mean Dissolved Oxygen	10.71	0.01
Minimum Dissolved Oxygen	2.38	0.13
Mean Turbidity	1.45	2.13

The inner group supports a relatively depauperate infauna, noteworthy for the fact that several of its regular inhabitants (*Capitella capitata, Schistomeringos longicornis,* and *Polydora ligni*) are frequently used as indicators of polluted or otherwise highly stressed environments. Table 6.6 gives a comparison of indicator species used in previous harbor studies. Abiotically, stations in this group characteristically have a low level of dissolved oxygen and high levels of the above-mentioned pollutants and indicators of low dissolved oxygen. In addition, the organic load in the inner stations is generally higher than elsewhere, as is the amount of oil and grease in the sediments, and the sediments are finer.

The channel group of stations is intermediate between the other two groups in most respects. Faunistically it supports an assemblage which is transitional between that of inner and outer station groups. The levels of pollutants are generally between the inner and outer extremes, as is the DO level.

The first axis in the discriminant analysis indicated a correlation between the biota and the dissolved oxygen, but also somewhat with sulfide, heavy metals, and IOD. The level of DO was higher at outer stations, the other factors were higher at inner stations. Since the chemical pollutants discussed are most abundant in areas where the oxygen levels become very low, their correlations with the biotic patterns are somewhat masked. In such conditions the lack of oxygen will make an area inhospitable to all but the most tolerant organisms no matter what the level of the various chemical pollutants.

High levels of sulfide are often associated with low DO (Reish, 1959). This results from a complex biochemical interaction wherein lack of oxygen precludes habitation by aerobic species of bacteria. Instead bacteria which metabolize sulfate compounds abound and these produce the H_2S. In a sense sulfide is an indicator of low DO in the sediments, as is IOD. Low DO and high H_2S, however, are both independently lethal to many organisms and may act synergistically when both are present (Theede, et al., 1969).

The lethal and sub-lethal effects of the heavy metals measured are well-documented on a variety of invertebrate organisms (see Reish and Kauwling, 1974; Chen and Eichenberger, 1976, for summaries). Many of the heavy metals react with the hydrogen sulfides to form metal sulfides; thus, in a low oxygen environment, some of the metals may be in this form. Whether the normally harmful metals are less effective in the relatively insoluble sulfide forms is not known. In an oxygenated environment effects similar to those seen in experimental studies may occur. The presence of large numbers of such contaminants, all well above the normal background levels, may produce a synergistic effect; i.e., the effects of all the metals acting at once is

Table 6.6

DOMINANT ORGANISMS REPORTED FROM LONG BEACH HARBOR IN AN INNER TO OUTER HARBOR ARRAY

Reish, 1959 →

Very Polluted	Polluted	Semi-healthy II	Semi-healthy I	Healthy
	Capitella capitata	*Cirriformia luxuriosa*	*Polydora paucibranchiata* *Schistomeringos longicornis*	*Tharyx ? parvus*

Hill, 1974 →

"Polluted" (station 24)	"Healthy" (station 27)
Capitella capitata *Capitita ambiseta* *Polydora ligni*	*Tharyx parvus* *Cossura candida* *Haploscoloplos elongatus*

AHF, 1975 →

Group Z	Group Y	Group X	Group W	Group V
Capitella capitata *Armandia bioculata* *Polydora ligni* *Pseudopolydora paucibranchiata*	*Schistomeringos long.* *Capitella capitata* *Ophiodromus pugetten.* *Theora lubrica*	*Euchone limnicola* *Callianassa* *Cryptomya calif.* *Nephtys c. franc.*	*Tharyx ? parvus* *Cossura candida* *Haploscoloplos elongatus* *Prionospio pinn.*	*Macoma acolasta* *Notomastus tenuis* *Prionospio pyg.* *Tellina modesta*

MBC, 1975 →

Group I	Group II	Group III	Group IV
Tharyx *Cossura candida* Capitellidae* *Euphilomedes*	*Tharyx* *Cossura candida* *Paraonis g. oculata*	*Tharyx* *Cossura candida* *Paraonis g. oculata*	*Tharyx* *Euphilomedes carcharodonta* Capitellidae* *Euphilomedes*

* *Capitella ambiseta* and *Mediomastus*.

greater than the sum of their individual effects. The same is true for DDT and PCB's. Figures 6.6 and 6.7 give examples.

It is important to realize that the level of any substance in an open system is governed by the rate at which it enters and the rate at which it is removed. In the harbor complex, input of pollutants - organic and inorganic, industrial and domestic, accidental and deliberate - is generally high in the slips and basins of the inner harbors. Removal from these areas is largely by passive transport in water currents, though some may be eliminated by evaporation and maintenance dredging. Theoretically with sufficient flushing pollutants would not accumulate, but would disperse and be diluted to sub-deleterious levels.

As indicated earlier, flushing of dead-end channels in the harbor is poor. Therefore, one might expect these locations to be depositional; this is confirmed by the finer sediments in station group Y than elsewhere in the harbor.

With regard to pollutants the situation is compounded because many of them bind to fine organic and inorganic particles. As these particles settle out under depositional conditions, the pollutants are carried with them to the benthos. Whether the bound form is more or less harmful to the organisms remains to be seen.

Seawater is generally oxygenated in two ways, as a by-product of photosynthesis carried out by the attached algae and phytoplankton and by diffusion from the atmosphere at the air-water interface. Both of these processes are restricted to the upper water column; since consumption of O_2 by animal and bacterial respiration continues well below the surface, vertical mixing is necessary to oxygenate the deeper water. The actual driving force for mixing may be wind or tidal currents, or even ships' propellers. However, just as relative lack of circulation in inner Los Angeles-Long Beach Harbors prevents outward transport of contaminants, it precludes adequate mixing of deoxygenated bottom water vertically with surface water at the same site or horizontally with outer harbor water.

The situation is complicated because of the high level of contaminants discharged into the inner harbor. Reducing chemicals and organics including petroleum wastes and even grass clippings from street run-off all make demands on the oxygen supply. Thus, the oxygen level in the sediments and overlying water may be reduced to the point that it becomes limiting to the existence of many benthic forms.

In the discriminant analysis, the second axis separates some of the channel stations (group X) from the rest of the stations. The higher turbidity of the water in group X is shown to be correlated with this separation. It can also be noted that the mean sediment size is also generally coarser in

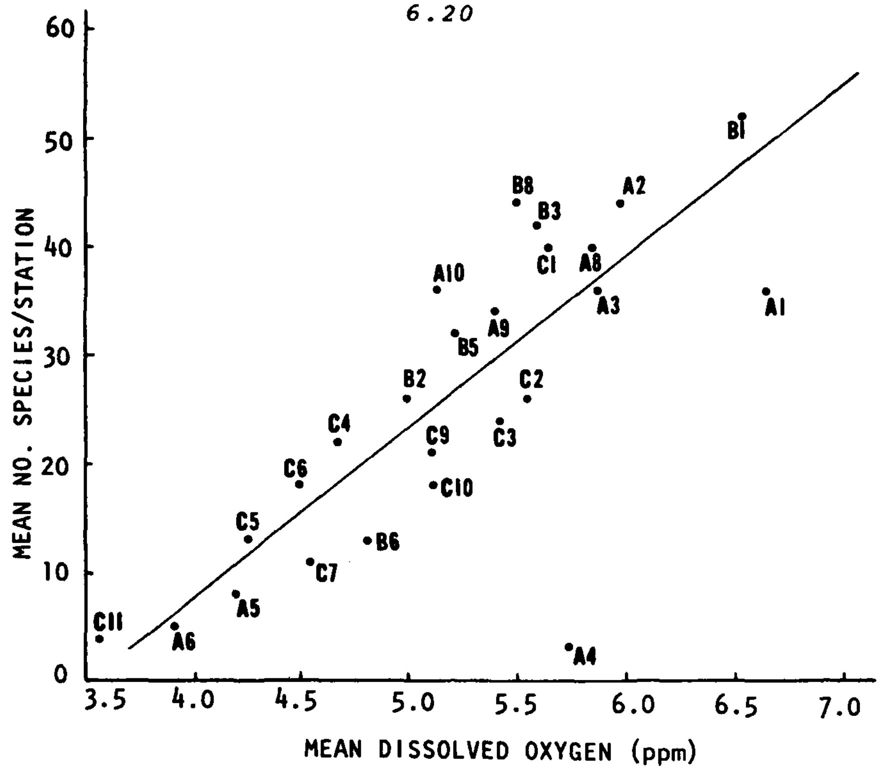


Figure 6.6. MEAN DO AND NUMBER OF BENTHIC SPECIES/STATION

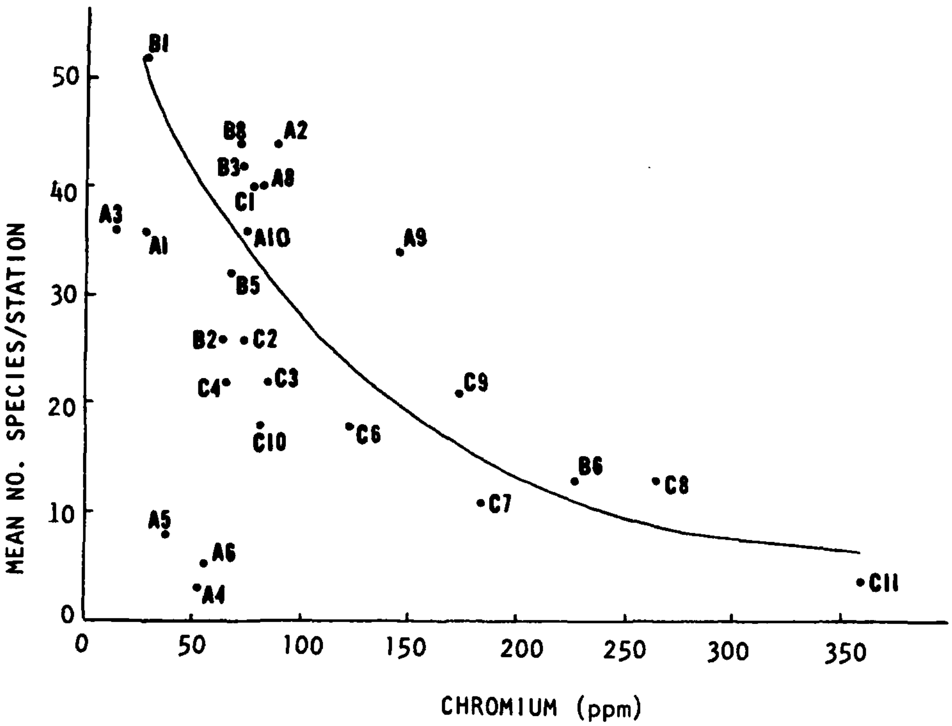


Figure 6.7. CHROMIUM AND NUMBER OF BENTHIC SPECIES/STATION

this group (with the exception of group V). These conditions probably result from water movement caused by wind and tidal currents as well as ship movement and propeller action. Disturbance of this sediment surface would resuspend primarily fine material. These fines, if moved toward dead end channels would settle there; if movement is toward the outer harbor, dispersion and dilution of the associated contaminants would result. Either way, the channel sediments would be coarser and relatively less contaminated as the evidence shows they are.

In terms of its biological effects, such disturbance of the sediments is problematic, however. On the one hand resuspension may aid the dispersion of polluted sediments and result in a more hospitable habitat. On the other hand, the wholesale resuspension of surface sediments probably dislodges the existing fauna and eliminates it; constant disturbance thus renders some sediment uninhabitable for some species. In addition the resuspension of sediment may release bound contaminants into the water, where they may be toxic to holoplanktonic forms and to the meroplanktonic larvae of other organisms.

The role of small but numerous benthic animals such as those which abound in the outer harbor is not generally appreciated perhaps because it is often poorly understood. But several contributions to the ecosystem can be mentioned:

1) They may serve as food for larger species, e.g., demersal fish and epibenthic crabs, which may be commercially important.
2) Many ingest the sediment, consuming some of the organic matter and rendering the rest more suitable for colonization by bacteria which further decompose this matter (Newell, 1965).
3) By their reworking of the sediment (Rhodes, 1974) they expose additional substrate to bacterial action and facilitate oxygenation of the deeper layers, making them habitable by still other organisms.

Outer Los Angeles Harbor may be viewed as a kind of sink, where many of the organics and contaminants discharged into both the inner and outer harbor are eventually deposited. By dilution the toxic components do not limit the kinds and numbers of species present, so a diverse and abundant assemblage is present. This assemblage constantly reworks the sediment and aids in the decomposition of complex organic materials, rendering them soluble and more easily dispersed.

In an area like Los Angeles-Long Beach Harbors, with a high input and/or accumulation of organics, such species may be important in reducing the total organic load of the sediment. Thus, the sink may act as a buffering zone between the highly contaminated inner harbor and the relatively unpolluted ocean beyond the breakwater.

Two anomalies appeared in the general pattern of biotic and abiotic parameters in the harbor. First is that station group Z appeared the most impoverished of the five stations, yet levels of pollutants were generally higher in group Y (Table 6.4, TOC, COD). In group Z, stations A4 to A7 in the outer harbor are all very close to fish cannery wastes and domestic sewage from the Terminal Island treatment plant. Station C11 has an especially high organic level, probably from petroleum wastes and surface run-off via Dominguez Channel. This high organic load is probably sufficient to depress oxygen levels to among the lowest in the harbor, in spite of moderate circulation at stations A4 through A7 because of their exposure to the open waters of outer harbor, and C11 because of the flow from Dominguez Channel. The very low oxygen, rather than very high toxins, probably limit the fauna in the Z group. The actual availability of some of the pollutants in the inner harbor may be low, because of adsorption and complexing, so that analytical readings would be higher than actual uptake.

The second enigma is the inclusion of stations A3, A8, and A11 adjacent to the wastes, along with A1 and B1 outside the harbor, in group V, the most diverse and least polluted group. Stations A3, A8 and A11 are topographically very close to A4 through A7 (station group Z, the most polluted grouping). Why are some of the faunistically richest stations adjacent to the poorest? The answer is that these locations probably benefit from increased circulation, lying as they do, just along the large gyre of outer harbor. Water coming in through Angels Gate in tidal flushing would be relatively oxygen rich, and help oxidize the organic load in its path. Even in the absence of high oxygen, the water flow would tend to carry reduced substance away and render the substrate predictably coarser, cleaner (and measured as such) and more habitable by sensitive organisms.

In summary, the available evidence indicates that the differences between outer and inner harbor are twofold in origin: high input of pollutants and generally poor circulation.

There is considerable difference between the impact of toxic trace and heavy metals, pesticides and refined petrochemicals, and natural wastes such as sewage and cannery effluent. Natural wastes impose heavy oxygen demands but can be assimilated readily into the food chain. Toxic wastes may inhibit, destroy or prevent certain faunal groups from inhabiting a given area.

If toxic inputs ceased, the present circulation would, with time, probably allow for eventual oxidation of contaminants and/or their removal from the immediate area. On the other hand, so long as input continues, dramatically improved circulation would be required before benthic conditions in the inner regions come to resemble those of outer harbor.

IMPACT

The effects of dredging on the marine benthos are of several sorts. They may be direct or indirect, immediate or delayed, permanent or temporary.

The dredging process itself will disrupt the benthos and affect benthic communities in one or all of three ways:

1) The processes of dredging and filling will resuspend quantities of bottom sediment; deposition of the fines in adjacent areas will eliminate species well removed from the actual site. Sessile infauna will be smothered and epibenthic organisms may suffer death from suffocation or the release of toxins by resuspension of contaiminated sediments; burrowing species will be least affected.
2) Landfill will irrevocably eliminate all individuals covered.
3) All animals will be eliminated from the dredge sites proper by the dredging.

The effects due to siltation in adjacent areas are highly complex and no attempt will be made to predict mortality of infauna due to siltation. Dredge fines have been shown to induce mortality among epifaunal organisms, but their effects on infauna is less well known. Vittor (1975) reported a decrease in benthic biomass in areas adjacent to dredge sites. This is something which can be followed empirically if the dredging is done.

The scope and location of proposed dredge and landfill operations are indicated in Figure 1.2. The present outer harbor area (indicated by heavy line) comprises approximately 16 km^2 (4,000 acres). Landfill during Phase I involves 1.2 km^2 in the vicinity of the Seaplane Anchorage of Los Angeles Harbor and a like amount adjacent to Pier J of Long Beach Harbor (cross-hatched). Phase II on the Los Angeles Harbor side involves 3.6 km^2 (stippled area). Proposed dredging may remove 30 million m^3 of harbor sediments.

Recent work by HEP indicated infaunal biomass in the outer harbor area of 20 gm/m^2 at inshore stations to 500 gm/m^2 in central portions. Using 200 gm (wet-weight)/m^2 as a conservative figure, some idea of the biomass to be eliminated can be attained.

It is estimated that Phase I landfill will result in the burying of 1.7×10^8 grams biomass in Los Angeles Harbor and the same amount in Long Beach Harbor. Phase II landfill will eliminate 5.1×10^8 grams more. A total of 8.5×10^8 grams (160 tons) of infaunal organisms will be irrevocably lost by burial; dredging will remove and destroy an additional 130 tons (6.8×10^8 grams).

Once dredging and filling operations are completed the newly dredged areas will undergo developmental changes. The question then is, whether former benthic conditions will be reestablished or whether development will proceed in another direction. Will changes prove to have been temporary or permanent? An examination of the literature provides some insights into the factors to be considered in predicting these effects.

Reish (1957) followed the development of benthic communities after dredging in the East Basin and Consolidated Slip areas of Los Angeles Harbor, which received wastes from the oil refineries. Prior to dredging, only five animal species were found at the seven stations sampled. After completion of dredging (2.5 years later) 10 species were recorded. Within another 1.5 years, however, the number fell to two, since wastes were still being discharged. Within a year after cessation, benthic species were collected there (Reish, 1971a). In a study of a newly dredged marina in nearby Alamitos Bay, Reish, (1961a), studied settlement of subtidal benthic organisms. The maximum number of species was attained just one year after the area was exposed to seawater. The number of species decreased steadily for the next two years as maturity and crosding occurred. The decrease was greater in the inner reaches of the marina where circulation was limited.

Similarly, an area of the lower San Gabriel River was found to have a black, sulfide substrate which supported no infaunal species. After dredging and reflooding, several marine invertebrates were recruited, at least one of which became reproductive (Reish, 1957).

Thus, post-dredging benthic development has several stages, depending upon the amount and nature of any pollutants discharged into the area and the water circulation. The sequence may be summarized as follows:

1) Creation of a new azoic substrate by dredging.

2) Primary modifications of the newly created marine enenvironment will occur with colonization by bacteria and accumulation of organic materials for food.

3) Larvae available from adjacent areas will settle and establish a relatively rich species community.

4) a. In the presence of adequate water circulation with high DO levels and absence of pollution, the relatively rich species community would persist for an indefinite period of time.

   b. With limited water circulation, low DO and pollution, there will be a gradual elimination of pollution-sensitive species with relatively few species but perhaps with large populations.

Biological predictions are difficult even when considerable background data are available, as is the case in the Los Angeles-Long Beach Harbors area. Predictions can be negated by changes in man's activity or in natural phenomena. Man may alter the environment, for example, by increasing waste discharges into the area or by accidents such as oil spills or a break in a sewer line. Climatic changes, especially abnormal increases in temperature, can cause changes in the harbor environment which could lead to dissolved oxygen depletion. Red tides, if severe, can also lead to dissolved oxygen reduction. On the basis of studies conducted in nearby Alamitos Bay (Reish, 1961a), some predictions can be made, realizing that changes in conditions could alter these.

A newly dredged area will be populated rapidly by those species which happen to be reproducing in adjacent waters at the time. Since no adult animals are present, large numbers of these larvae will settle and grow. Since they are small, there is little inter- or intraspecific competition. After a relatively short period of time (4-8 months), the actual population of benthic animals is large in terms of numbers of individuals, but small in biomass. Later, competition for food and space will occur, as well as predation, and the population will be reduced by natural biological interaction. A degree of stability will be reached within two years, with the exception of some pelecypods which have a longer life span. The benthos should contain about 25-30 species. After about two years in areas of limited water circulation, the population will be reduced if there are wastes discharged into the area or if the DO should drop significantly below 5.0 ppm. It is possible that some of the pollutants from other areas in the harbors may be carried into these new areas depending upon the currents. If so, this could lead to a deterioration of the benthos in these new areas.

Initial bacterial modification of the newly exposed sediments would occur quickly and sufficient organics for food will accumulate rapidly. Information from several sources (Reish, 1961; 1971, this report, Ch. 5) suggests that many of the common benthic species of the harbor are reproductive during much of the year; within a year virtually all species will reproduce at least once. Therefore, a wide range of larvae will be available for settlement in disrupted parts of the harbor. Settlement of species with non-pelagic larvae will be delayed in remote parts of new basins and channels. The dispersion of pelagic larvae into areas without reproductive benthic adults will be limted by two factors: flushing by water containing the larvae, and the concentration of toxic substances in the areas. Larvae, though produced abundantly in areas not affected by dredging, may not be transported to the new sites, or may suffer high mortality if transferred there.

In Chapter 2 of the present study, it was shown that there are correlations between the abiotic factors in the sediments

of the harbor and the faunal units found in those sediments. The faunal assemblages, in turn, are characterized in terms of kinds and numbers of organisms present. Correlation does not prove a causal relationship between abiotic and biotic measures, but on the basis of cited experimental work with the various abiotic factors, this relationship was demonstrated. The biotic conditions result from the prevailing physico-chemical environment. The physico-chemical conditions themselves are determined by interactions between the input of chemicals into an area, and their removal from that area. In the inner harbor the level of a variety of contaminants is high and water circulation is poor.

The impact of proposed dredge and landfill must be viewed in light of the harbor ecosystem. By evaluating the effect of landfill on water movement we can work backward through the above scheme and predict the nature of future communities of benthic organisms. That dredging and landfill can alter water circulation patterns has been documented recently in the literature, as has a consequent alteration in community structure. Kaplan et al. (1974) measured changes in current velocities and sedimentation patterns after a navigational channel was dredged through a shallow lagoon. These changes were accompanied by significant reductions in biomass, numbers of species, and numbers of individuals in the area.

Any landfill in the outer harbor will disrupt the existing patterns of water movement there to some extent. The degree of disruption will be a function of the size and location of the landfill. Thus Phase I, which is smaller and more peripheral than Phase II, will be less disruptive. The arm of Phase I in Los Angeles Harbor sticks into the gyre and will interfere with it; perhaps smaller gyres will develop on either side of this jetty and so maintain moderate water movement and benthic conditions similar to those presently found. On the other hand, the interference will be as great as that anticipated from Phase II.

The magnitude and location of Phase II is such that its construction is certain to have considerable and permanent effects on the nature of the remaining benthos. Figure 1.2 reveals that proposed Phase I-II construction combined eliminates 40% of the present outer harbor. Importantly, it is centered so that no large-scale gyres or other persistent water circulation could possibly exist. The land mass created will also alter the present wind patterns in the harbor region. The prevailing westerly winds presently have a fetch of about 6 km over open outer harbor waters and probably contribute significantly to circulation in the harbor. Interruption of this fetch will not only reduce wind-induced water movement in the outer harbor, but also in the channels and West Basin of Long Beach Harbor, which are in the lee of new land.

Assuming that the input of pollutants remains the same, the effect of poorer circulation and less flushing will be the accelerated accumulation of pollutants and reduced DO over most of the remaining sediments. These, of course, will lead to reductions in the number of species. In addition, the work includes the formation of one large and several smaller basins plus several miles of channels. As documented in Chapter 11, it is in such basins and channels that pollutants are most concentrated in the sediments, DO is poorest, and the fauna most impoverished.

In general terms, the landfill proposed will result in a wholesale seaward shift of conditions now obtained in the harbor. For example, areas now characterized as outer harbor in station group X will accumulate additional pollutants, have less DO and support a fauna now characteristic of inner harbor (Y). Conceivably, conditions at stations group Y and Z will deteriorate to the point that they support no benthic fauna.

Newly created benthos should undergo a developmental period, during which settlement of larvae will occur. Within two years the assemblage in new channels and basins should resemble that in the main channel group of stations, i.e., moderately high levels of pollutants but adequate DO and a diverse (25-30 species) benthic assemblage. However, because circulation in these new areas will not be good, the benthos will eventually deteriorate, and very high levels of pollutants with very few species (< 10) can be expected in a few years.

Several more specific predictions are possible: 1) the West Basin of Long Beach Harbor (U.S.Navy Shipyard) was not sampled during the HEP study, but a monthly benthic survey was made in 1970-71 by Hill and Reish (1975). Examination of these data indicated that the benthic assemblage at the closed west end of the basin resembles that of the present Z group and the open east end is like the Y group.

Phase II landfill (Figure 1.2) will create a new basin south of West Basin of approximately the same size and shape and will remove West Basin about 4 km from open, well-aerated water. This distance will result in decreased flushing, continued deposition of pollutants, and lower levels of DO. Eventually, conditions throughout the West Basin will deteriorate, attaining a fauna which resembles that in the depauperate station group Z of the present harbor benthos.

The benthos of the new basin might acquire characteristics now found in West Basin - fauna of group Z in the west and of group Y in the east - since the location and configuration would be similar, but would have the advantage of being closer to the harbor entrance.

There is the suggestion in Figure 1.2 that conditions between Angels Gate and the main channel of Los Angeles Harbor

will be largely unaffected by the proposed operations. This area is presently relatively pollution-free and supports a varied benthic assemblage (station group V and W) on a relatively coarse substrate. It might be argued that the dredging would increase flow and keep the area clean. However the large amount of landfill in the outer harbor will decrease the total volume of water in the harbor and so less tidal water will flow through Angels Gate (the speed will be further reduced if the channel is deepened). Flushing for the area between the main channels and Cabrillo Beach may well become depositional in nature, as opposed to its status now.

The likelihood of deposition in this area is increased if the present discharges (two of fish cannery wastes and one domestic sewage) in the vicinity of Fish Harbor are not eliminated or relocated. As planned, Phase I alone will create a semi-enclosed basin with restricted circulation and concentration of these wastes.

The reduction in area of bottom of the outer harbor will reduce its capacity as a sink for the wastes discharged into the inner harbor. Given the same levels as the present input of toxic substances, the reduction of bottom area by 50% or more would virtually double the concentrations in the remaining benthos, thus reducing the kinds of organisms that can live there. Even if the present kinds of infaunal organisms do return, by simple reduction in area only about half as many individuals will be present; the total capacity of outer harbor to assimilate toxins and recycle organics will diminish proportionately. The elimination of toxic waste discharges and point source control, such as are intended in the National Pollutant Elimination System (NPDES) regulations, would, on the other hand, ameliorate the build-up of toxic substances in the sediments. The extent to which this might occur cannot be predicted at this time.

LITERATURE CITED

Chen, K.Y. and J.C.S.Lu. 1974. Sediments compositions in Los Angeles-Long Beach Harbors and San Pedro Basin. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part VII. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 1-177.

Chen, K. and B.Eichenberger. 1976. Concentrations of trace elements and chlorinated hydrocarbons in marine fish. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 11. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. Appendix II, p. 283-298.

Day, J.H., J.G.Field, and M.P.Montgomery. 1971. The use of numerical methods to determine the distribution of the benthic fauna across the continental shelf of North Carolina. J. Anim. Ecol.40:93-125.

Grassle, J.F. and J.P.Grassle. 1974. Opportunistic life histories and genetic systems in marine benthic polychaetes. J. Mar. Res. 32:253-284.

Green, R.H. 1974. Multivariate niche analysis with temporally varying environmental factors. Ecology 55(1):73-83.

Harbors Environmental Projects. 1976. Biotic Environment. In Port of Long Beach Master Environmental Setting.

Hill, L.R. 1974. A seasonal environmental study of the polychaetous annelids within the Long Beach Naval Station and Shipyard, Long Beach, California. Master's Thesis, Calif. State Univ., Long Beach. 97 pp.

Hill, L.R. and D.J.Reish. 1975. Seasonal occurrence and distribution of benthic and fouling species of polychaetes in Long Beach Naval Station and Shipyard, California. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 8. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 57-74.

Hurlbert, S.H. 1971. The non-concept of species diversity: A critique and alternative parameters. Ecology 52(4):577-586.

Kaplan, E.H., J.R.Walker and M.G.Kraus. 1974. Some effects of dredging on populations of macrobenthic organisms. Fisheries Bull. 72(2):445-480.

Newell, R. 1965. The role of detritus in the nutrition of two marine deposit feeders. Proc. Zool. Soc. London 144:25-45.

Reish, D.J. 1957. The effect of pollution on marine life. Industrial Wastes, Sept.-Oct., 1957. p. 114-118.

Reish, D.J. 1959. An ecological study of pollution in Los Angeles-Long Beach Harbors, California. Allan Hancock Foundation Occasional Papers 22:1-119.

Reish, D.J. 1961a. A study of benthic fauna in a recently constructed boat harbor in southern California. Ecology 42(1): 84-91.

Reish, D.J. 1961b. The use of the sediment bottle collector for monitoring polluted marine waters. Calif. Fish and Game 47:261-272.

Reish, D.J. 1971a. Effect of pollution abatement in Los Angeles Harbors. Marine Pollution Bull. 2(5):71-74.

Reish, D.J. 1971b. Seasonal settlement of polychaetous annelids on test panels in Los Angeles-Long Beach Harbors, 1950-1951. J.Fish.Res.Bd.Canada 28(10):1459-1467.

Reish, D.J. and T.J.Kauwling. 1974. Marine and estuarine pollution. J.Water Poll. Contr. Fed. 46(6):1437-1451.

Rhodes, D.C. 1963. Rates of sediment reworking by *Yoldia limatula* in Buzzards Bay, Massachusetts, and Long Island Sound. J.Sed. Pet. 33(3):723-727.

Robinson, K. and H.Porath. 1974. Current measurements in the outer Los Angeles Harbor. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part VI. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 1-91.

Smith, R.W. 1973. Numerical analysis of a benthic transect in the vicinity of waste discharges in outer Los Angeles Harbor. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part II, Biological Investigations. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 193-237.

Soule, D. and M.Oguri. 1972. Circulation patterns in Los Angeles-Long Beach Harbor. Drogue study: Atlas and Data Report. In Marine Studies of San Pedro, California. D.Soule and M.Oguri, eds. Part I. Allan Hancock Fdtn. and Sea Grant Program, Univ. So. Calif., Los Angeles.

Stephenson, W., W.T.Williams, and S.D.Cook. 1974. The benthic fauna of soft bottoms, southern Moreton Bay. Mem. Qd. Mus. 17(1):73-123.

Theede, H., A.Ponat, K.Hiroki and C.Schlieper. 1969. Studies on the resistance of marine bottom invertebrates to oxygen-deficiency and hydrogen sulfide. Mar. Biol. 2(4):325-337.

Vittor, B.A. 1975. Effects of channel dredging on biota of a shallow Alabama estuary. J.Mar. Sci. Alabama 2(3):111-134.

Chapter 7

ICHTHYOLOGY

7.1

ICHTHYOLOGY

INTRODUCTION

Intensive studies of the fish populations of the Los Angeles-Long Beach Harbors and adjacent waters were undertaken in 1972 by the University of Southern California Harbor Environmental Projects of the Allan Hancock Foundation, in cooperation with the Environmental Biology program at Occidental College.

Funded cooperatively, the studies were supported by the U.S. Army Corps of Engineers, the Pacific Lighting Corporation, and the USC Sea Grant Institutional Program (Department of Commerce).

A preliminary survey of harbor fish populations consisting of fourteen ten-minute bottom trawls with a 15-foot semi-balloon otter trawl, was done on the Vantuna in the outer Los Angeles-Long Beach Harbor on May 24, 1972, by D. W. Chamberlain. According to Chamberlain (1973), trawling in depth of 20 to 60 feet yielded 3100 fish belonging to 28 species, representing 15 families and 7 orders, for an average of 221 fish per trawl. Five species made up 85% of the total catch. The most abundant species caught was the speckled sanddab, *Citharichthys stigmaeus* Jordan and Gilbert. Larvae, juveniles and adults of a number of species were captured.

White croaker, *Genyonemus lineatus* (Ayres), taken near sewage outfall areas, had a high incidence of caudal fin erosion. Speckled sanddabs taken in the same area had a high incidence of infestation by isopod parasites.

Condition factors for white croaker and white seaperch, *Phanerodon furcatus* Girard, from the harbor showed that these two species were heavier for their length than fish from open coast areas.

The most recent previous work on fish in the harbor was a study of the California halibut, *Paralichthys californicus* (Ayres), made by the California Department of Fish and Game near Long Beach during the four-year period, 1956-1960 (Young, 1964). The general condition of fish taken at the time was "poor". White seabass, *Cynoscion nobilis* (Ayres), and white croaker, *Genyonemus lineatus*, taken then had exophthalmia. Spotted turbot, *Pleuronichthys ritteri* Starks and Morris, were thin and in "very poor" condition (Young, 1964). The term "poor" was used by Young (1964) to describe the state

of the fish. Pollution was suggested as the factor influencing these conditions.

Considerable information has recently been collected by a number of workers on benthic fish populations in southern California. The areas sampled are located along the California coast from Pismo Beach south to San Diego and seaward to the northern Channel Islands, and also include Santa Catalina Island, Cortes and Tanner Banks. Areas that have received considerable attention include: Santa Monica Bay, Palos Verdes shelf, and San Pedro Bay (Carlisle, 1969; A.J. Mearns, M.J. Allen and M. Sherwood, 1973; A.J. Mearns, M. J. Allen, M.J. Sherwood and R. Gammon, 1973; A.J. Mearns and M.J. Allen, 1973; A.J. Mearns, M.J. Allen and M. Sherwood, 1974; SCCWRP, 1974; D.Hotchkiss, Los Angeles County Southern Sanitation District, pers. comm.; and J.S. Stephens, Occidental College, pers. comm.).

Fish populations in three nearby harbors have previously received greater attention than the Los Angeles-Long Beach Harbor complex. Fish populations and behavior studies were conducted at King Harbor in Redondo Beach (J.S. Stephens and H. Hickman, Occidental College, pers. comm.). Reish (1968) did biological surveys of Alamitos Bay which included the resident fishes. Fish sampling surveys were done in Anaheim Bay (Lane, 1971).

The fish populations in Los Angeles-Long Beach had not been studied to any extent since 1960 until the present study was begun in 1972. The increased use of the harbor by shipping and industry, by anglers and use by commercial bait boats, plus the possible effects of clean-up efforts begun in 1968-69, indicated that an assessment of the fish populations in the harbor was badly needed.

Studies by Stephens, Gardiner and Terry (1973) of demersal fishes of San Pedro Bay, outside of Los Angeles-Long Beach Harbor, were made on 61 trawls between 1970 and 1973. Community analysis was carried out showing that the five characteristic deep water species all have a center of distribution north of Pt. Conception. The mid-depth species group was consistently variable, and the strongest shallow water association was between three species of flatfish.

Because demersal fishes of southern California have not been exploited by a trawl fishery, there has been a dearth of information concerning local ground fish populations. The only studies available, prior to 1969, were occasional trawling explorations by state or federal fisheries agencies. The first comprehensive trawl study for southern California was

Carlisle's (1969) 6-year analysis of fish populations adjacent to the Hyperion sewage discharge in Santa Monica Bay. In 1971 Ebling et al. published a shallow water trawl survey carried out as part of the Environmental Protection Agency sponsored study of the 1969 Santa Barbara Oil Spill. Recently the Southern California Coastal Water Research Project (SCCWRP, 1973, 1974) has published a review of unpublished data on the coastal fish populations of southern California. That review includes much of the data presented by Stephens, et al. (1973), but it is reasonable to present the San Pedro Bay data separately since these populations may be considered as baseline studies in the examination of the fishes of Los Angeles-Long Beach Harbor.

The harbor waters may support as rich a fish fauna, if not richer, than that of adjacent waters. The average catch figure of 221 fish/trawl for the harbor is high compared to shallow San Pedro Bay collections by Stephens et al. (1973). The average in the harbor even included two trawls with a total of only four fish; one of these was interrupted when the net was ripped, which would not normally be considered in averaging data. Average catch outside the harbor varied with depth: 252.4 fish in 10-30 meters, 291.6 in 30-90 m., with an overall average of 273.5 fish/trawl. All of these tows deeper than 30 meters, however, represent an estimated 20-minute bottom time and below 100 meters they actually represent considerably longer periods. SCCWRP estimated the area trawled by the Vantuna (16' net, 20-minute tow) as 7,540 m^2. Stephens' shallow water studies and Chamberlain's trawls represent only half that area, 3,770 m^2. If density is estimated, based on the estimated area and mean catch size, the harbor and inshore waters appear to support a relatively rich fish fauna compared to that of the adjacent areas. Deeper water, 30-400 meter trawls, averaged 316 fish for an estimated area of 7,540 m^2 or an estimated density of 1 fish per 23.9 m^2. Stephens' shallow water study averaged 252.4 fish for an area of 3,770 m^2 or a density of 1 fish per 12.5 m^2.

It appears from Chamberlain's preliminary study (1973) that the fauna of Los Angeles-Long Beach Harbors and the adjacent sandy or sand-mud shelf are basically similar. The degree of interchange between fish stocks of these two areas is of great importance in any speculation concerning recruitment to the harbor or the use of harbor waters as a nursery of shelf fishes. There is some indication, however, that, at least in white croaker populations (Phillips, Terry, and Stephens, 1972), the harbor elements are endemic.

Stephens, Terry and Allen (1974) reported on the abundance, distribution and seasonality of fish populations in

the harbor as follows: 76 trawls were made in Los Angeles-Long Beach Harbor, between May 24, 1972 and October, 1973. A total of 57,647 fish were collected for an overall average of 738.5 fish/trawl. If larval fishes are excluded the average, 423.2/trawl, is still exceptionally high, with a fish density of one fish per 8.9 square meters, the highest recorded locally. The diversity and richness within the harbor ($\bar{X}_D$=1.29, $\bar{X}_R$=10) approximates that recorded for similar depths outside of the harbor. Three areas of distribution are recognized within the harbor: an area rich in flatfishes, an area of high croaker abundance, and an area demarcated by the presence of rockfishes. The area rich in croakers seems to correlate with nutrient enrichment (sewage) and perhaps relatively low oxygen tension. The ecological parameters of harbor species are possible factors in abundance and distributional statistics. Changes in seasonal abundance were documented, showing fewer fishes present in winter than in summer. The standing crop of fishes in the harbor is estimated between 700,000 and 1,600,000 kg. The annual productivity is estimated at 56 percent of the standing crop of 392,000-896,000 kg. This represents 7.3-16.5 kg/m^2.

HARBOR VS. SAN PEDRO BAY

The 65 species of fishes taken during study represents about half the number of species reported by Chamberlain (1974) in his check list of Los Angeles-Long Beach Harbor fishes, but it includes the majority of common resident species.

In order to supplement the trawling study, three diving stations along the inner rocky face of the middle breakwater, and three gill net stations (middle breakwater and Cerritos Channel) were added. (Figure 7.1).

The total of 57,647 fish taken in the 76 trawls in this study includes all specimens, and is highly biased by 1973 July-September collections which included 25,487 young, just settling white croakers (*Genyonemus*), most of which probably would not have survived in this concentration. If the settling croakers are removed, the total becomes 32,160 or an average of 423.2 fish per trawl. This figure is considerably higher than the mean catch in Stephens' San Pedro Bay trawls and almost doubles the figure from Chamberlain's original data (221 fish per trawl). Based on an area of 3,770 m^2 per trawl, the density of one fish per 8.9 m^2 of substrate is the highest recorded for trawling studies in the San Diegan Warm Temperate. Mearns, Allen, Sherwood and Gammon (1973) recorded a median catch of 494 fish per trawl off Palos Verdes (21 stations, 9 November to 11 December 1972), but this survey used a 40'

trawl and the estimated area of each trawl was 10,160 m^2 (SCCWRP, 1973) so the density of fish is relatively low: one fish per 20.6 m^2. The same stations at Palos Verdes during May-June (1972) had an even lower catch per trawl of 214 fish (Mearns, Allen, and Sherwood, 1973) or a density of one fish per 47 m^2.

The richness and diversity of fishes in the harbors can be compared with 19 of the 54 SCCWRP stations cited above that were from a similar depth, shallower than 30 meters. The average richness for the SCCWRP sample was 11 species (range 6-17) with an average Shannon-Weaver diversity index of 1.28 (range 0.44-1.94). The average richness in the harbor is 10 species (range 4-18) while the Shannon-Weaver diversity averages 1.29 (range 0.65-2.08). It appears that the diversity and richness within the harbor is at about the same level as adjacent waters of a similar depth. SCCWRP (1973) cites considerably higher mean diversity indices for the Southern California Bight, but these represent variations in depth to 400 meters which would certainly increase total diversity. Thirteen San Pedro Bay species have not been taken in the harbor, while seven harbor species were not reported in the San Pedro Bay study.

The abundance ranking of species within the harbor changed from that reported by Chamberlain (1973) after further work. The 11 most abundant species and their percent score are listed below in order of overall abundance. The figure in parentheses is the percentage, when recruited post-larval *Genyonemus* are excluded from the data. *Genyonemus lineatus*, 52.4 (14.6); *Engraulis mordax*, 17.1 (30.7); *Symphurus atricauda*, 8.9 (15.9); *Citharichthys stigmaeus*, 6.5 (11.6); *Seriphus politus*, 3.8 (6.8); *Cymatogaster aggregata*, 3.7 (6.7); *Phanerodon furcatus*, 3.6 (6.6); *Porichthys myriaster*, .76 (1.4); *Lepidogobius lepidus*, .7 (1.3); *Sebastes miniatus*, .6 (1.1); *Pleuronichthys verticalis*, .5 (.9). It should be noted that this ranking is strictly numerical and ignores relative biomass completely. The only changes in ranking resulting from the exclusion of larval white croakers occur in the top three species. The ranking becomes *Engraulis*, *Symphurus*, *Genyonemus*. Anchovies and young white croakers, which make up 69 percent of the catch by number, are plankton feeders, and their abundance probably reflects the nutrient enrichment of the harbor. The only significant change in overall abundance in these data as compared to Chamberlain's preliminary study is the increase in northern anchovies (15th to 2nd), white croakers (3rd to 1st), and queenfish (10th to 5th).

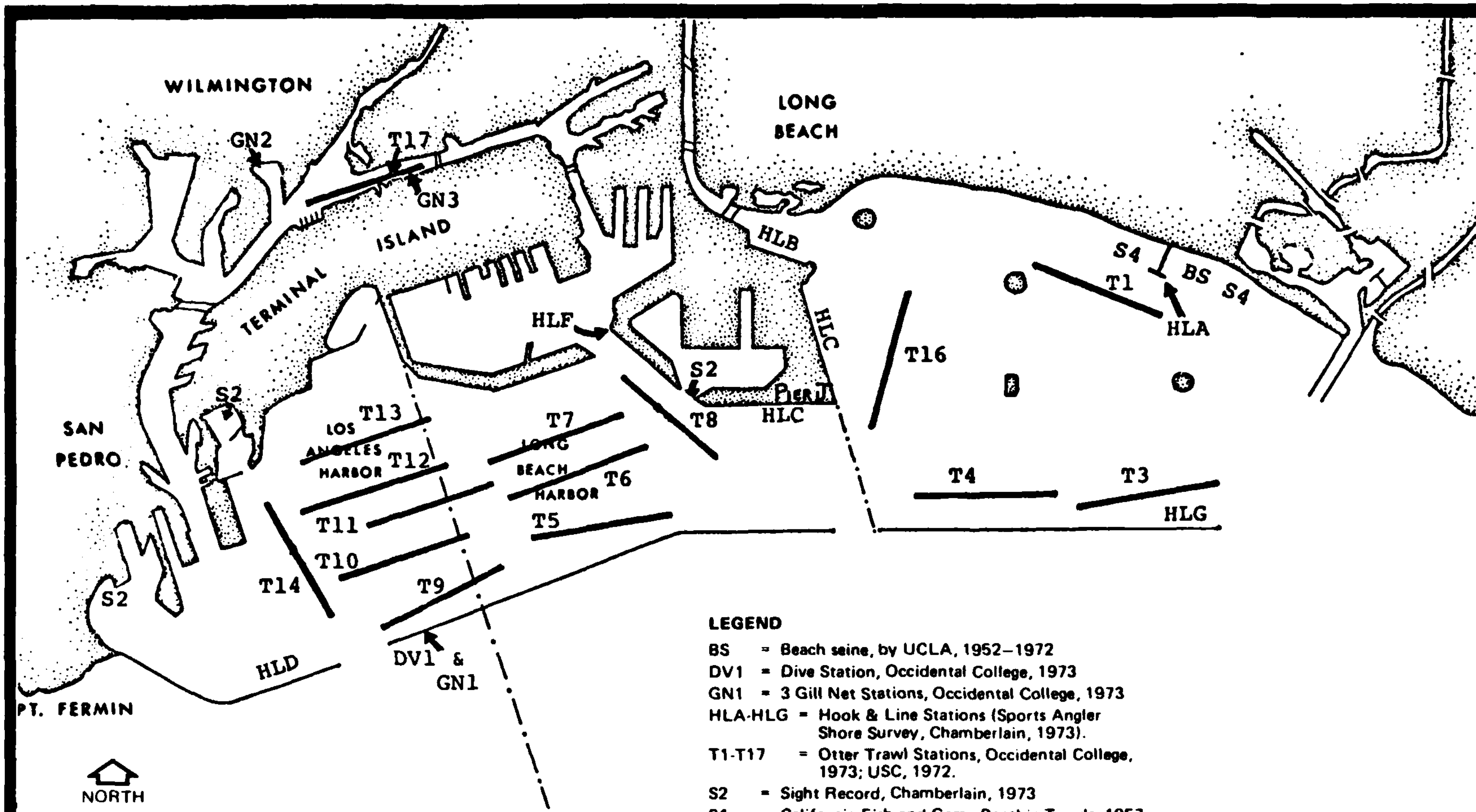
DISTRIBUTION WITHIN THE HARBOR

There is an uneven distribution within Los Angeles Harbor. Figure 7.2 illustrates this overall pattern of distribution. Three distributional areas are recognized in Stephens' trawling pattern: 1) an area at the western end of the outer harbor that is generally high in flatfish species (Stations 9, 10, 11, 12 and 14) but relatively low in fish abundance; 2) an area from the eastern opening of the harbor to the mouth of Fish Harbor and probably including Cerritos Channel (Stations 3, 4, 8, 13 and 17) that has few flatfish species, is relatively low in richness but high in abundance of certain species, particularly croakers; 3) and an area adjacent to the middle breakwater that is high in rockfish abundance.

This series of studies by Chamberlain, Stephens, and others has increased the numbers of fishes known to frequent or inhabit the harbor to 132 species in 48 families. In 1972, the U. S. Army Corps of Engineers listed over 50 species thought to inhabit the harbor (1972, draft EIS). In 1928, Ulrey and Greeley had listed marine fishes collected at nine dredge and five trawl stations in southern California within the area now enclosed by the outer Los Angeles-Long Beach Harbor breakwater. At the time of their collections, only the San Pedro portion of the breakwater existed, extending east about 2 miles from Cabrillo Beach. They collected or reported collections by contemporary workers of some 47 fish species from this vicinity, i.e., Cabrillo Beach to Alamitos Bay.

During the years 1956 to 1960, the California Department of Fish and Game conducted a study of the California halibut, *Paralichthys californicus,* in the Belmont Shores area of the harbor and adjacent ocean waters to the south. In addition to the halibut, 40 other species were collected (Parke Young, California Department of Fish and Game, Long Beach, California, pers. comm.).

The Los Angeles-Long Beach Harbors have an assemblage of various substrates including a sandy-mud bottom, rocky bottom, rock and concrete breakwaters, wood and concrete pilings, sandy beaches, estuaries, and small islands. At mean lower low water, depths in the outer harbor range from about 3 feet in shoal areas to a deep of 72 feet just across the Long Beach Channel from the entrance to the Southeast Basin. The average harbor depth is approximately 37 feet. Given such varied habitats and the difficulty in taking adequate samples from some of these areas,undoubtedly the species list will still be found to be incomplete, and not without error or omission.



LEGEND

BS = Beach seine, by UCLA, 1952–1972
DV1 = Dive Station, Occidental College, 1973
GN1 = 3 Gill Net Stations, Occidental College, 1973
HLA-HLG = Hook & Line Stations (Sports Angler Shore Survey, Chamberlain, 1973).
T1-T17 = Otter Trawl Stations, Occidental College, 1973; USC, 1972.
S2 = Sight Record, Chamberlain, 1973
S4 = California Fish and Game Benthic Trawls, 1957.

Source: Chamberlain, 1973

FIGURE 7.1

LOCATION OF LOS ANGELES–LONG BEACH HARBOR FISH SURVEYS TO 1974

The appended checklist includes those fish taken or observed within the harbor west of an imaginary line running from Belmont Shores to the east end of the Long Beach breakwater, and the area north of Long Beach, Middle and San Pedro breakwaters. (p. 7.48, Appendix I).

The known range of each species is given in Chamberlain (1974) in order to provide information for assessing potential effects of proposed alterations in depth or temperature in the harbor.

Figure 7.1 shows bottom trawling stations (T1-T17), sport anglers fishing sites (HLA-HLG) and gill netting sites (GN1-GN3). Diving observations were made along the harbor side of the outer breakwaters by Ron Williamson (University of Southern California, pers. comm., S1 annotated fish) and by John Stephens, Jr. (Occidental College, pers. comm., DVI, annotated fish). Numbers and letters listed under each species and after the words "Los Angeles-Long Beach Harbor" refer to location and method of capture, if known; the list is appended, pp. 7.48-7.62. Collection methods, depth and positions are unavailable for S1 and S3 annotated fish. Fish annotated with "U&G" are species which were listed as being taken in the harbor area by Ulrey and Greeley prior to 1928.

The following sections of this chapter deal with various phases of the ichthyology of the harbor. Surveys of Fish Eggs and Larvae are reported by Gary D. Brewer, Ph.D., and a discussion of the impact of harbor development on the anchovy summarizes previously published research by Brewer on the anchovy. John S. Stephens, Ph.D., of Occidental College, discusses the impact of the proposed master plan on fish populations in the harbor.

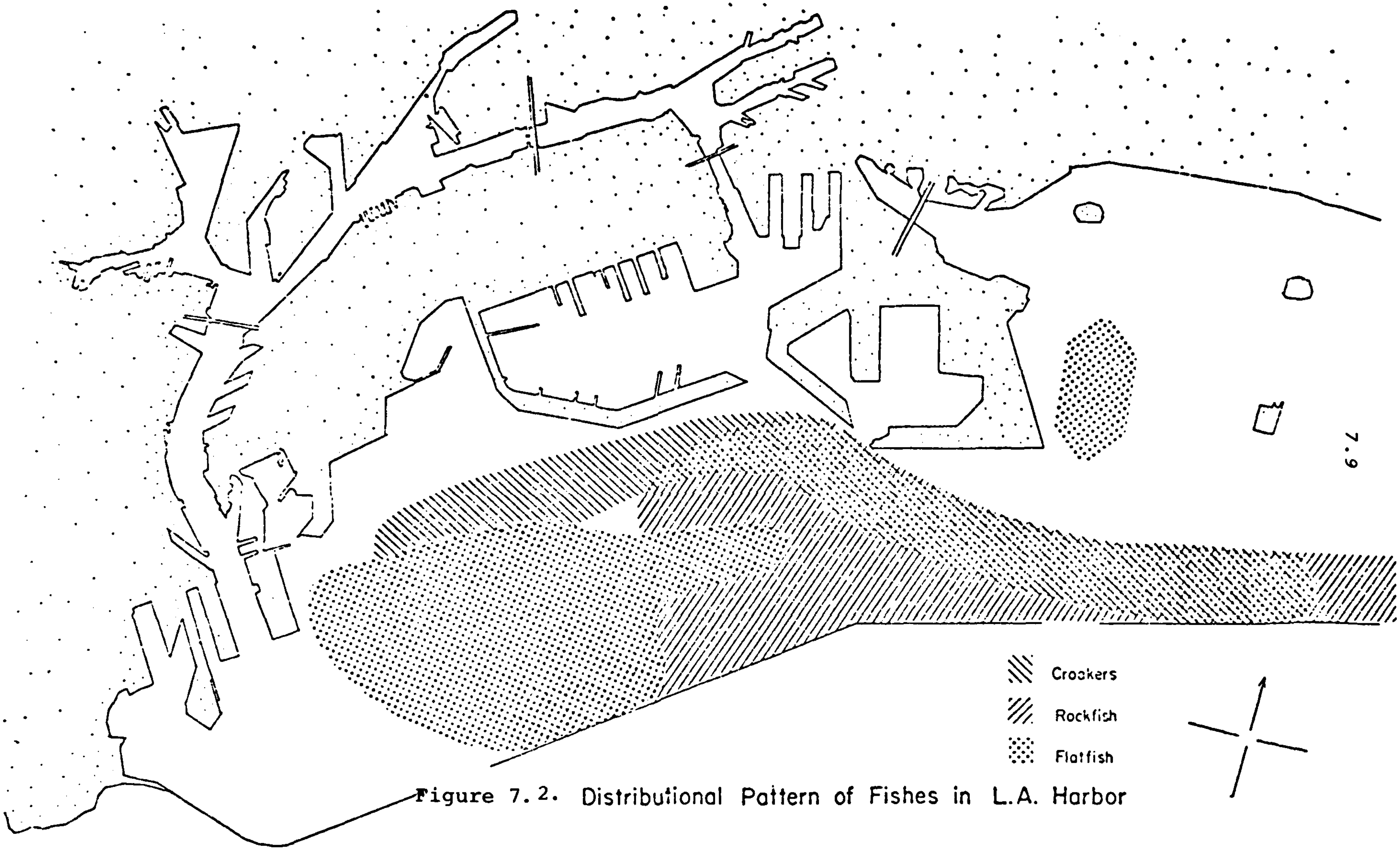


Figure 7.2. Distributional Pattern of Fishes in L.A. Harbor

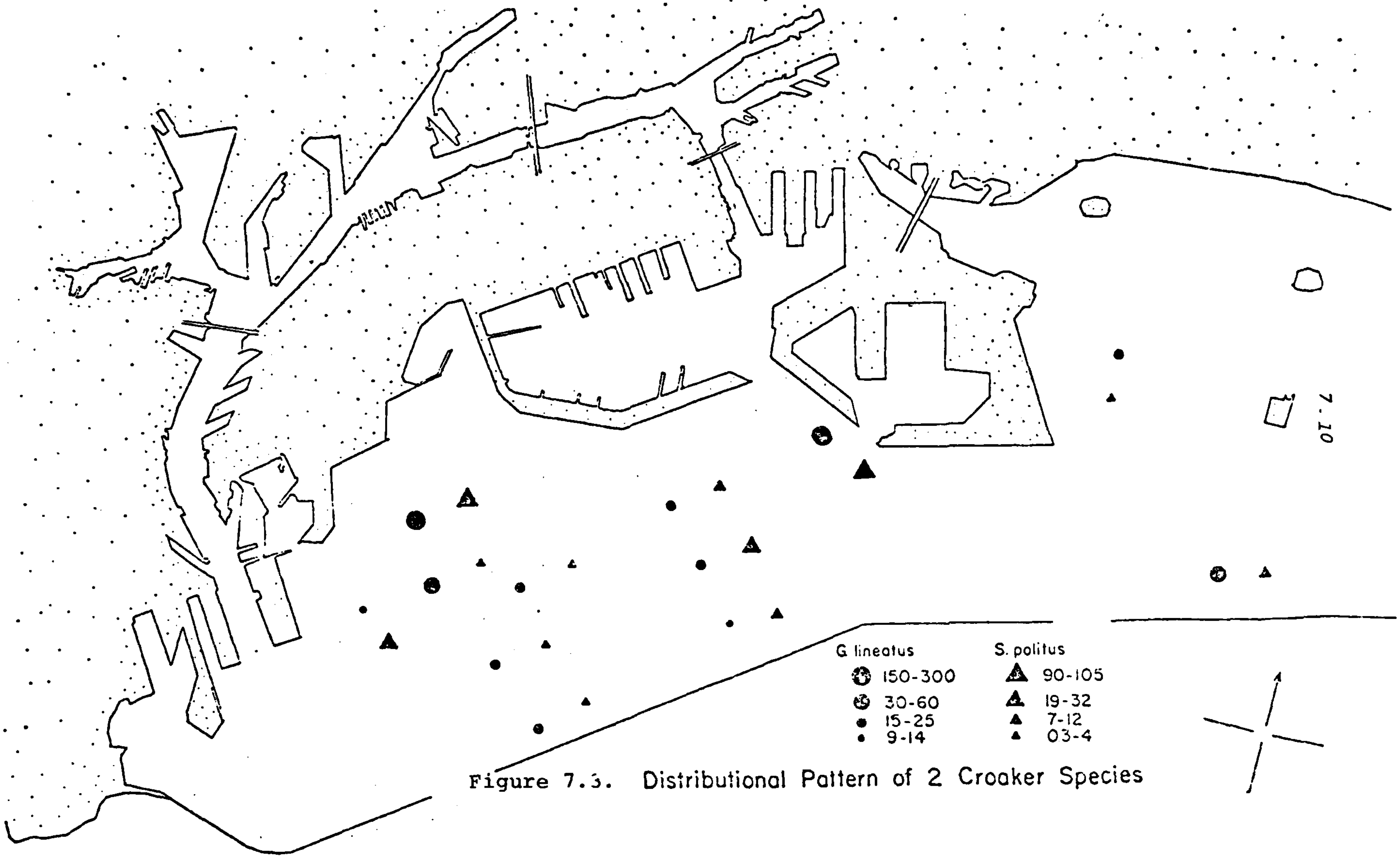


Figure 7.3. Distributional Pattern of 2 Croaker Species

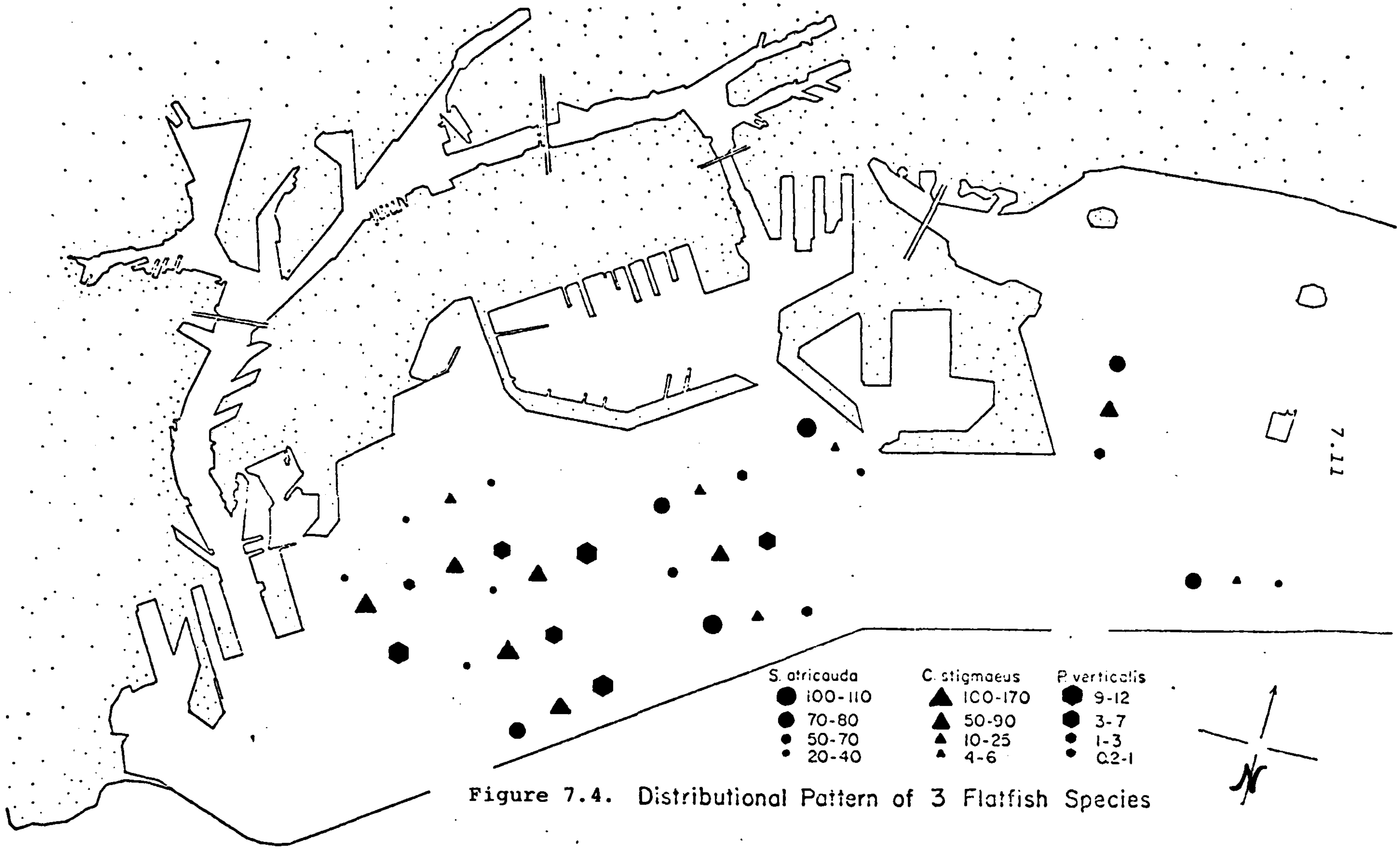


Figure 7.4. Distributional Pattern of 3 Flatfish Species

7.12

FISH EGGS AND LARVAE IN SAN PEDRO BAY

INTRODUCTION

In order to assess the importance of the Los Angeles-Long Beach Harbor as a fisheries nursery, a study of the abundance, distribution, and seasonal occurrence of fish eggs and larvae in San Pedro Bay was made, based on 561 plankton trawls taken in the Los Angeles-Long Beach Harbor and San Pedro Bay between February, 1973 and September, 1974.

The inshore larval fishes of the California coast have not been studied comprehensively and are virtually unknown. This is in contrast to data available on estuarine and inshore ichthyoplankton from the coastal Atlantic states (McHugh, 1966, 1967), and the intensive effort to identify and enumerate pelagic fish larvae in offshore areas throughout the California Current system (Ahlstrom, 1959, 1967, 1969; Moser, 1967; Moser and Ahlstrom, 1970; Richardson, 1973).

The inshore environment, especially harbors, bays, estuaries, has come under close scrutiny in recent years in relation to man's recreational and industrial impact. Yet, knowledge of how these areas function as potential spawning and nursery grounds for fishes is lacking. The importance of such knowledge in understanding the abundance, distribution and dynamics of marine fishes has been discussed by Ahlstrom (1965, 1968). Although Stephens et al. (1974) and Chamberlain (1973, 1974) have documented the occurrence of juvenile and adult fishes in the harbor, it is unwise to speculate as to which species actually or potentially reproduce here.

MATERIALS AND METHODS

Figure 7.5 is a map indicating the trawl sites monitored during the study and Table 7.1 gives pertinent data concerning the number of trawls taken at each station, the inclusive trawl dates, bottom depths and bottom substrates over each trawl site. The survey began with biweekly samples taken at 15 stations in the outer harbor and just outside the harbor breakwater; later more stations were added in the main channels of the inner harbor and adjacent areas outside the harbor. Eventually 22 stations were monitored. Each series of trawls (35 total) was taken in the morning and early afternoon on the same day, except one series (May, 1974) which was taken at night. During July, August, and September, 1974, only one series was taken each month and only six stations were sampled. No samples were taken during June, 1974.

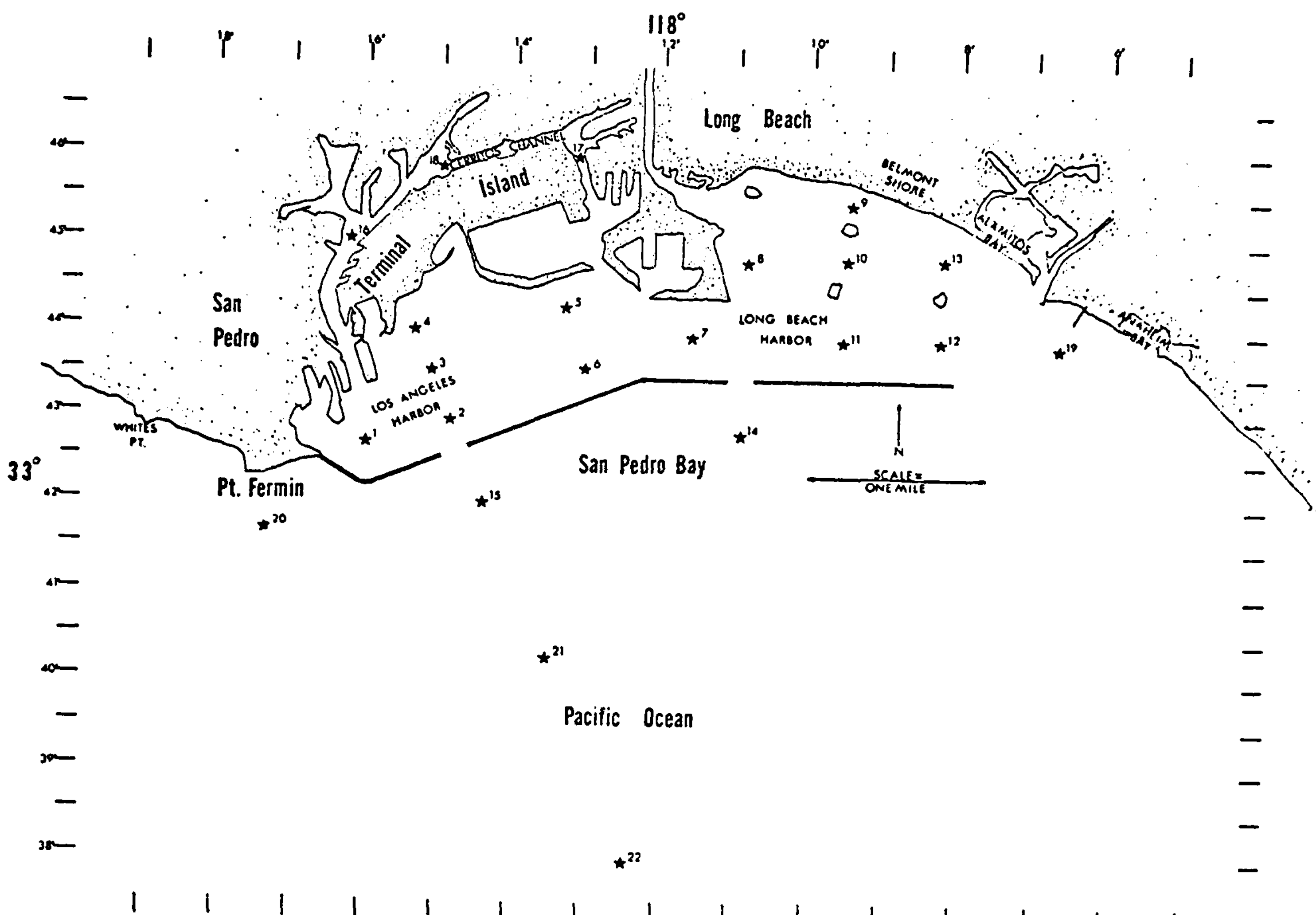


Figure 7.5. Location of 22 plankton stations indicated by numbered stars.

Table 7.1. Plankton trawl station data.

Station No.	Bottom Depth (m)	Bottom Type	Inclusive Trawl Dates	No. of Trawls
1	12	mud	2/22/73 - 5/22/74	32
2	12	mud	2/22/73 - 9/07/74	35
3	9	mud	2/22/73 - 9/07/74	35
4	6	mud	2/22/73 - 9/07/74	35
5	11	mud	2/22/73 - 5/22/74	32
6	20	mud	2/22/73 - 5/22/74	31
7	16	mud	2/22/73 - 5/22/74	32
8	12	sand	2/22/73 - 5/22/74	32
9	7	sand	2/22/73 - 5/22/74	31
10	11	sand	2/22/73 - 5/22/74	32
11	16	sand	2/22/73 - 5/22/74	32
12	12	sand	2/22/73 - 5/22/74	32
13	7	sand	2/22/73 - 5/22/74	32
14	19	sand	2/22/73 - 5/22/74	30
15	19	mud	2/22/74 - 9/07/74	35
16	11	mud	4/12/73 - 5/22/74	29
17	11	mud	11/11/73 - 5/22/74	15
18	11	mud	1/12/74 - 5/22/74	11
19	7	sand	3/23/74 - 5/22/74	6
20	21	rocky	3/23/74 - 5/22/74	6
21	23	sand	7/20/74 - 9/07/74	3
22	36	rocky	7/20/74 - 9/07/74	3

Every sample was taken with a 0.5m, 333μ mesh (nylon) conical plankton net, trawled at approximately 2 knots for 5 minutes. All trawls were made by G. Brewer from a small skiff. Trawling depth was maintained at approximately 4m by adjusting the angle of inclination of the cable. A calibrated rotometer was used to determine the volume of water strained during 40 of the carefully timed, standardized trawls. The mean volume of water strained was $50.5m^3$ (range 43-57; a standard deviation 5.1; standard error of the mean 0.8). Plankton samples were immediately preserved in 5 percent formalin in sea water and later sorted in the laboratory for fish eggs and larvae with the aid of a dissecting microscope. Large plankton samples were aliquoted by a Folsom splitter in order to count the abundant eggs; however, each aliquot was examined carefully for larvae, which were removed and identified.

SPECIES COMPOSITION

Over 100,000 fish eggs and larvae were captured during the 20-month trawling period. The catch was dominated by fish eggs, but only anchovy *(Engraulis mordax)* and sardine *(Sardinops sagax caeruleus)* eggs were specifically identified. Among the larvae, at least 45 taxa, representing 19 families, have been distinguished. Until comparative material is obtained, specific identification of a number of undescribed forms is impossible.

Table 7.2 gives a list of larval taxa, including the number of individuals captured and the number of times they occurred in the trawls out of the 561 recorded trawls. Those families represented by the greatest number of individuals included the Engraulidae (anchovies), with 3,618 larvae; Blenniidae (blennies), with 2,027 larvae; Sciaenidae (croakers), with 1,712 larvae; Scorpaenidae (rockfish), with 840 larvae; Gobiidae (gobies), with 532 larvae; Pleuronectidae (flatfish), with 258 larvae; Clinidae (clinids), with 166 larvae; Pomacentridae (damselfish), with 158 larvae; Cottidae (sculpins), with 138 larvae; Serranidae (sea basses), with 134 larvae; Bothidae (flatfish), with 40 larvae; and Labridae (labrids), with 27 larvae.

SEASONALITY

Figure 7.6 shows the number of fish eggs and larvae captured by month as a function of the number per cubic meter of water filtered. Peak spawning occurred in the month of February, dropped sharply in March and April and reached the lowest values in the late summer and early fall.

Table 7.2. Kinds and abundance of larval fishes from the Los Angeles-Long Beach Harbor and San Pedro Bay, February, 1973 to September, 1974.

	Total No.	No. of Occurrences
Engraulidae		
Engraulis mordax	3818	221
Atherinidae		
unident. atherinids (2)	14	9
Syngnathidae		
Syngnathus sp.	10	8
Serranidae		
Paralabrax spp.	134	53
Pomadasyidae		
Anisotremus davidsoni	7	7
Scieanidae		
unident. sciaenids	1712	194
Pomacentridae		
Chromis punctipinnis	156	4
Hypsypops rubicondus	2	1
Labridae		
unident. labrids (3)	27	21
Sphyraenidae		
Sphyraena argentea	1	1
Clinidae		
unident. clinids (5)	166	95
Blenniidae		
Hypsoblennius spp. (2)	2027	235
Gobiidae		
unident. gobiids (4)	532	145
Scorpaenidae		
Sebastes spp.	840	77
Cottidae		
unident. cottids (8)	138	95
Agonidae		
unident. agonid	2	1

Table 2.--continued

Bothidae		
Citharichthys sp.	3	3
Paralichthys californicus	15	13
Xystreurys liolepis	22	11
Pleuronectidae		
Hypsopsetta gutulata	85	45
Parophys vetulus	45	17
Pleuronichthys decurrens	28	21
Pleuronichthys verticalis	100	42
Brotulidae		
Brosmophycis marginata	2	2
Gobiesocidae		
unident. gobiesocid	36	27
Unidentifed eggs	84931	535
Unidentified larvae	24	19

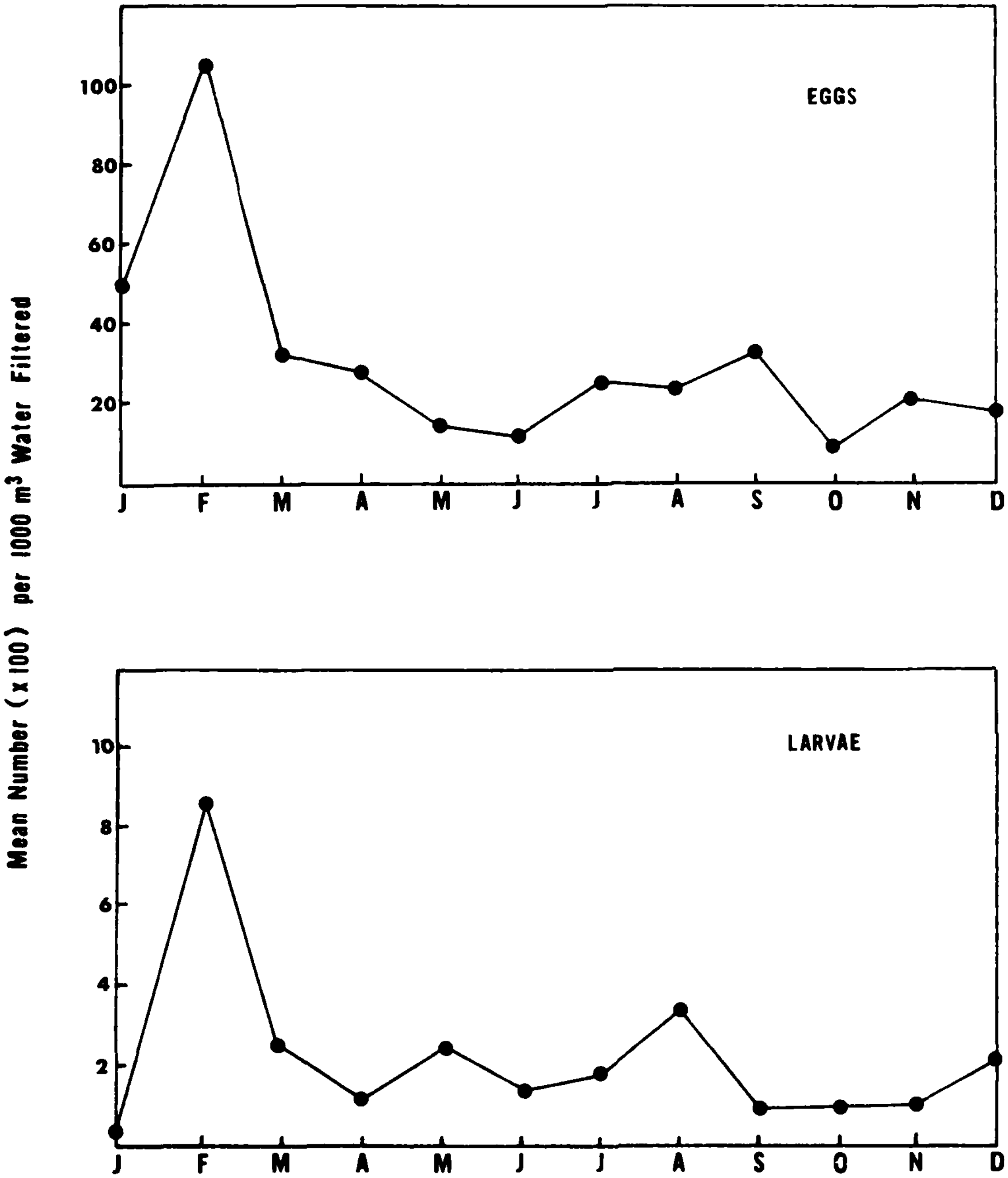


Figure 7.6. Number of fish eggs and larvae captured each month from San Pedro Bay (excluding anchovy eggs and larvae).

The environmental factors that affect gonad maturation release of gametes, and development and growth of embryos and larvae of fishes are complex, multidimensional, and are the subject of a voluminous literature. No obvious, direct correlation exists between the primary productivity, nutrient availability, or zooplankton density data, summarized elsewhere, with the abundance of fish spawning. Temperature and photoperiod have classically been considered as dominant controlling factors in teleost reproductive cycles (de Vlaming, 1972). The very rapid increase in egg and larval abundance in February coincided with the increasing temperatures and photoperiods of late winter; this may be the key triggering factor for reproduction by harbor fishes.

HORIZONTAL VARIABILITY

A great deal of variability in the kinds and numbers of fish larvae occurs within relatively short distances between station sites. This seems to reflect very different physical, chemical, or biological parameters which are required or tolerated by various species of fish.

Table 7.3 lists the twelve most abundant families of larval fishes captured in San Pedro Bay. Each station is ranked by abundance according to the number of larvae captured per cubic meter of water filtered.

Data from Table 7.3 was used in Figures 7.8-7.18 to plot the key distribution patterns of fish larvae in San Pedro Bay. The top 5 ranking stations for each of the 12 families have been circled in Figures 7.7-7.18. Those stations which caught the fewest larvae under each family have been designated by squares. Because stations 21 and 22 were sampled only three times each, they have not been included in the analysis in Figures 7.7-7.18. Stations 19 and 20 have been included, but their limited number of samples during only one season may slightly bias the data. Figure 7.19 shows the 5 top ranking stations on the basis of total number of fish eggs captured (excluding anchovy eggs).

DISCUSSION

Stephens, et al. (1974), on the basis of otter trawl data, gave the following abundance ranking of fishes in the harbor based on juveniles and adults:

Genyonemus lineatus (Sciaenidae)
Engraulis mordax (Engraulidae)
Symphurus atricauda (Cynoglossidae)
Citharichthys stigmaeus (Bothidae)
Seriphus politus (Sciaenidae)
Cymatogaster aggregata (Embiotocidae)
Phanerodon furcatus (Embiotocidae)
Porichthys myriaster (Batrachoididae)
Lepidogobius lepidus (Gobiidae)
Sebastes miniatus (Scorpaenidae)
Pleuronichthys verticalis (Pleuronectidae)

Among the top ranking families listed above, the live-bearing embiotocids are not likely to be caught by plankton net because the young are fairly developed, fast swimmers immediately after being spawned. Also, the batrachoidids have strictly benthic larval stages and would be missed by surface plankton tows. Notable by their absence in plankton collections are the tongue sole (*Symphurus*: Cynoglossidae) (none collected) and the sanddabs (*Citharichthys*: Bothidae) (only 3 individuals). Although juveniles and adults of these two species are abundant in the harbor their larvae are apparently not. These species may spawn in deeper waters outside the harbor or the vertical distribution of the larvae may be deeper than 4m.

The most notable exception in the rankings by Stephens et al. (1974) with the present plankton data is the complete absence of blennies (Blennidae) in the otter trawl data. Juvenile and adult blennies prefer rocky habitats which are difficult to sample effectively by nets.

Perusal of Figures 7.7-7.19 shows conclusively that the Los Angeles-Long Beach Harbor is an important spawning area for a variety of fishes. Although spawning by several families of fishes including the Engraulidae, Scorpaenidae, Pleuronectidae, and Bothidae is most intense in areas outside the harbor breakwater, significant numbers of larvae are taken within the harbor where proposed dredge and land fill operations will occur. These families of fishes have significant commercial and/or sport fishing value. It seems likely that land fill within the harbor will exclude many of these desirable fishes.

It is apparent that several species in the families Sciaenidae, Blenniidae, and Gobiidae are restricted to near-shore habitats and find the confined waters of the harbor as a very suitable habitat to live and reproduce. These families will probably suffer some from habitat elimination in the outer harbor; however, these are the families that will populate and dominate the fish fauna within the restricted channels and shipping lanes in the proposed landfilled harbor.

Table 7.3. Trawl stations ranked by larval fish abundance according to the number of larvae captured per cubic meter of water filtered (X 10^3).

Trawl Station	Engraulidae (anchovy) No.	Engraulidae (anchovy) Station rank	Blenniidae (blennies) No.	Blenniidae (blennies) Station rank	Sciaenidae (croakers) No.	Sciaenidae (croakers) Station rank
1(32)*	49	17	54	14	18	20
2(35)	119	8	71	11	35	16
3(35)	131	7	38	18	38	14
4(35)	70	13	75	10	92	5
5(32)	66	15	140	4	75	7
6(31)	113	9	83	8	34	18
7(32)	39	19	84	7	51	12
8(32)	44	18	49	17	57	11
9(31)	68	14	53	15	152	2
10(32)	79	11	77	9	66	9
11(32)	61	16	94	5	38	15
12(32)	183	5	93	6	108	4
13(32)	96	10	66	13	84	6
14(30)	620	1	31	19	35	17
15(35)	351	3	70	12	61	10
16(29)	8	22	14	22	7	22
17(15)	29	20	167	3	133	3
18(11)	18	21	27	20	49	13
19(06)	77	12	50	16	20	19
20(06)	433	2	23	21	17	21
21(03)	193	4	340	1	160	1
22(03)	147	6	280	2	73	8

* Number of trawls at each station

Table 7.3 (continued)

Scorpaenidae (rockfish) No.	Station rank	Gobiidae (gobies) No.	Station rank	Pleuronectidae (flatfish) No.	Station rank	Clinidae (clinids) No.	Station rank
4	17	34	5	3	18	4	13
19	8	11	12	7	12	11	5
13	10	13	9	7	11	3	17
17	9	15	8	7	13	7	7
11	12	9	13	6	14	5	10
12	11	6	18	8	9	5	11
21	6	8	14	6	15	9	6
6	15	12	10	6	16	3	15
8	14	23	6	13	4	0	20
9	13	15	5	10	7	6	8
21	7	2	20	11	6	6	9
63	3	12	11	24	1	13	4
113	2	8	15	16	2	3	16
167	1	7	16	11	5	4	12
34	5	2	19	7	10	2	19
0	18	77	3	2	19	3	18
4	0.2	61	4	13	3	17	2
0	18	120	1	4	17	22	1
0	18	80	2	0	20	17	3
40	2	7	17	10	8	3	14
0	18	0	21	0	20	0	20
0	18	0	21	0	20	0	20

Table 7.3 (continued)

Trawl Station	Pomacentridae (damselfish) No.	Pomacentridae (damselfish) Station rank	Cottidae (sculpins) No.	Cottidae (sculpins) Station rank	Serranidae (sea basses) No.	Serranidae (sea basses) Station rank
1	0	6	4	12	6	5
2	0	6	5	10	8	4
3	0.6	5	5	11	0	18
4	0	6	8	4	3	10
5	0	6	4	13	2	14
6	0	6	3	15	0.6	17
7	0	6	9	2	2	13
8	0	6	2	17	4	9
9	0	6	7	6	3	12
10	0.6	4	0.6	18	8	3
11	0	6	6	7	4	8
12	1.3	3	7	5	8	2
13	0	6	6	8	1	15
14	0	6	6	9	5	7
15	0	6	8	3	0.6	16
16	0	6	2	16	3	11
17	0	6	15	1	40	1
18	0	6	0	19	6	6
19	0	6	3	14	0	18
20	0	6	0	19	0	18
21	173	2	0	19	0	18
22	853	1	0	19	0	18

Trawl Station	Bothidae (flatfish) No.	Station rank	Labridae (labrids) No.	Station rank	Unidentified eggs No.	Station rank
1	1	6	3	2	2224	15
2	3	2	4	1	4178	6
3	0.6	8	2	4	3680	9
4	0	9	2	6	2550	12
5	0	9	0.6	9	2208	16
6	0.6	8	0.6	8	3366	10
7	0.6	8	0	10	3918	8
8	0.6	8	0.6	9	2014	17
9	0.6	8	0	10	1086	20
10	0.6	8	0.6	9	1882	18
11	2.5	3	0	10	1856	19
12	10	1	2	5	4092	7
13	1	5	0	10	2436	13
14	2	4	0.7	7	5558	4
15	1	7	0	10	6152	2
16	0	9	0	10	156	22
17	0	9	0	10	3081	11
18	0	9	0	10	726	21
19	0	9	0	10	4484	5
20	0	9	3	3	2364	14
21	0	9	0	10	12680	1
22	0	9	0	10	5760	3

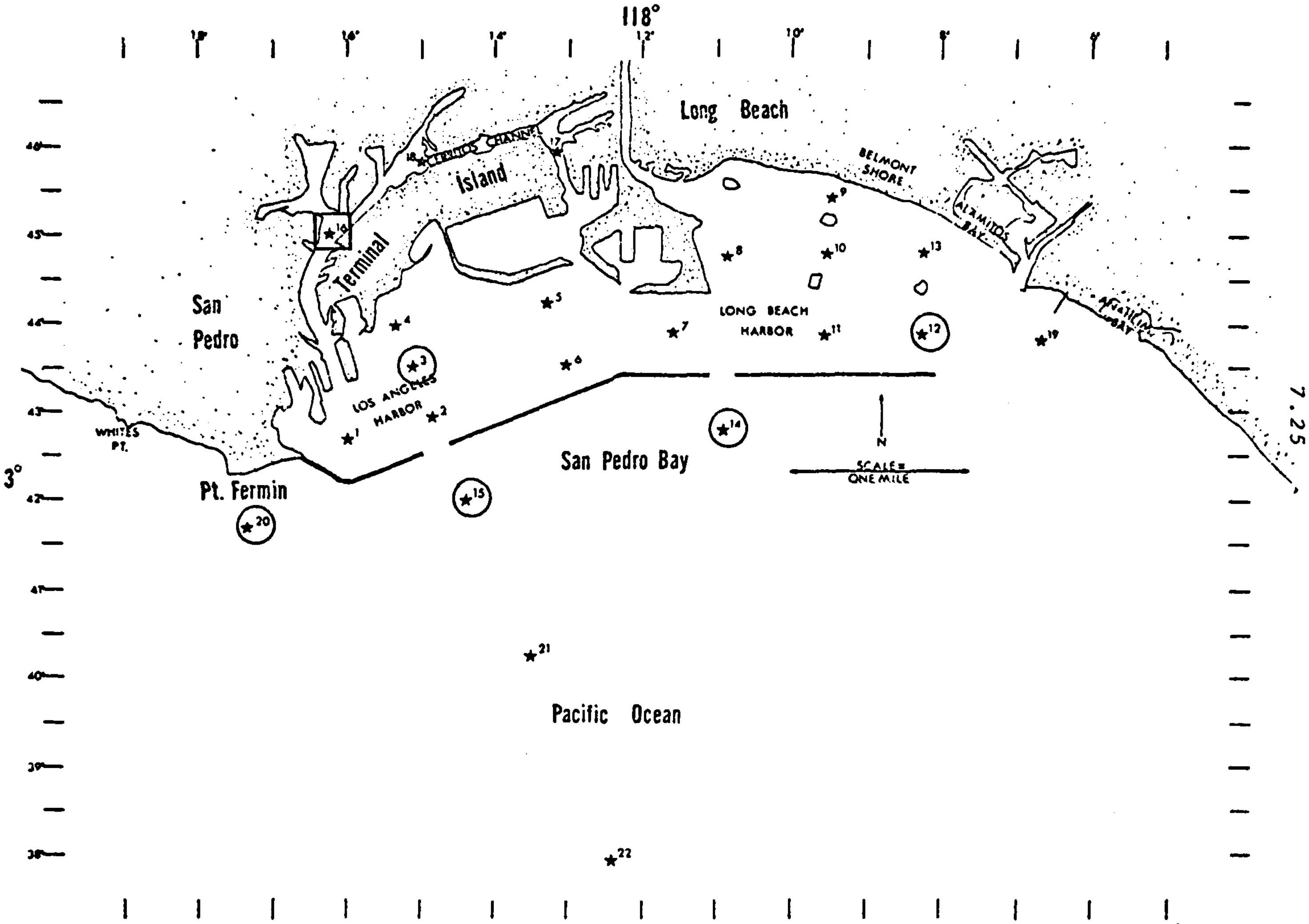


Figure 7.7 - Engraulidae. Circled stations represent top 5 ranking stations; squared station represents the bottom ranking station.

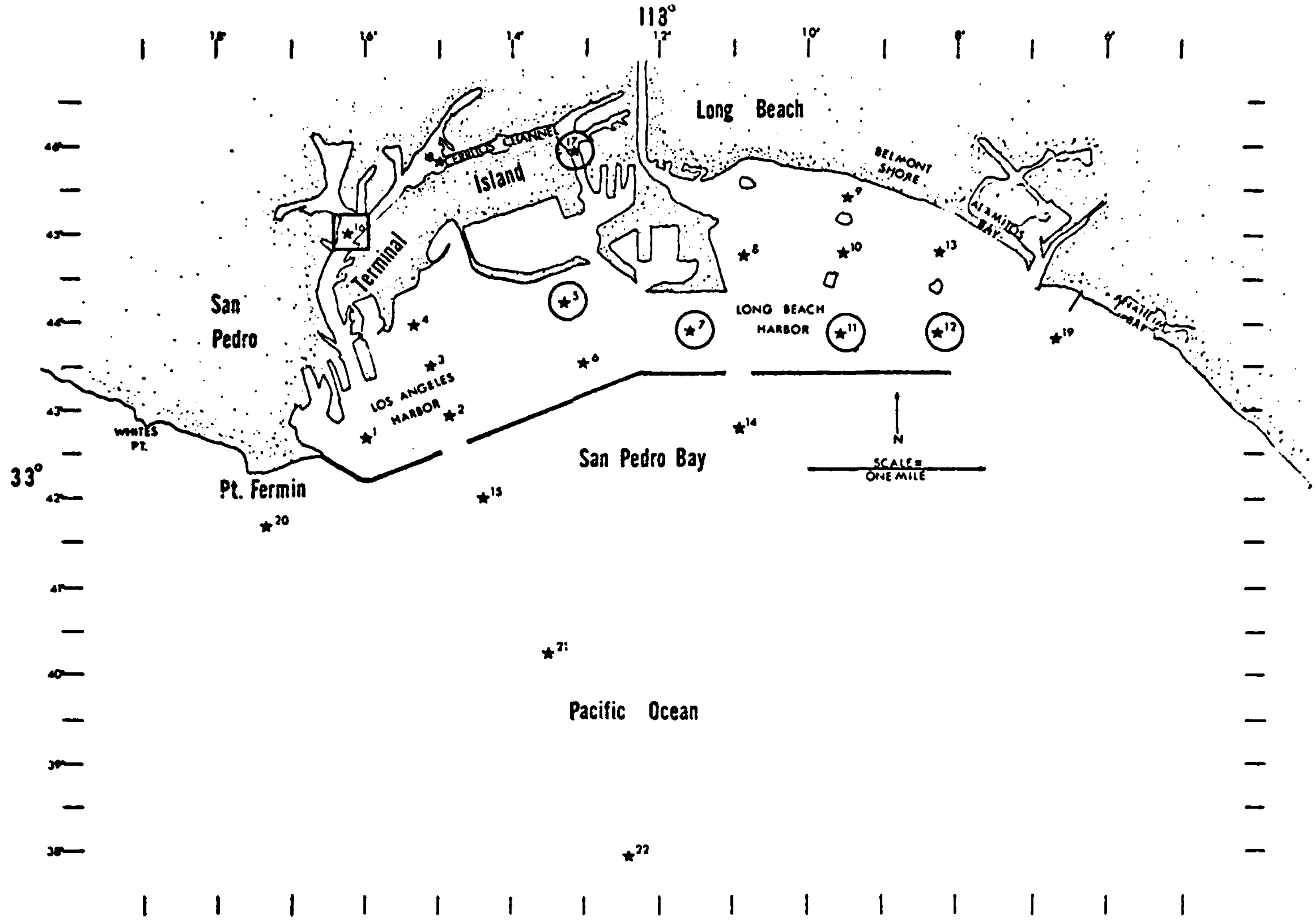


Figure 7.8 - Blenniidae. Circled stations represent top 5 ranking stations; squared station represents the bottom ranking station.

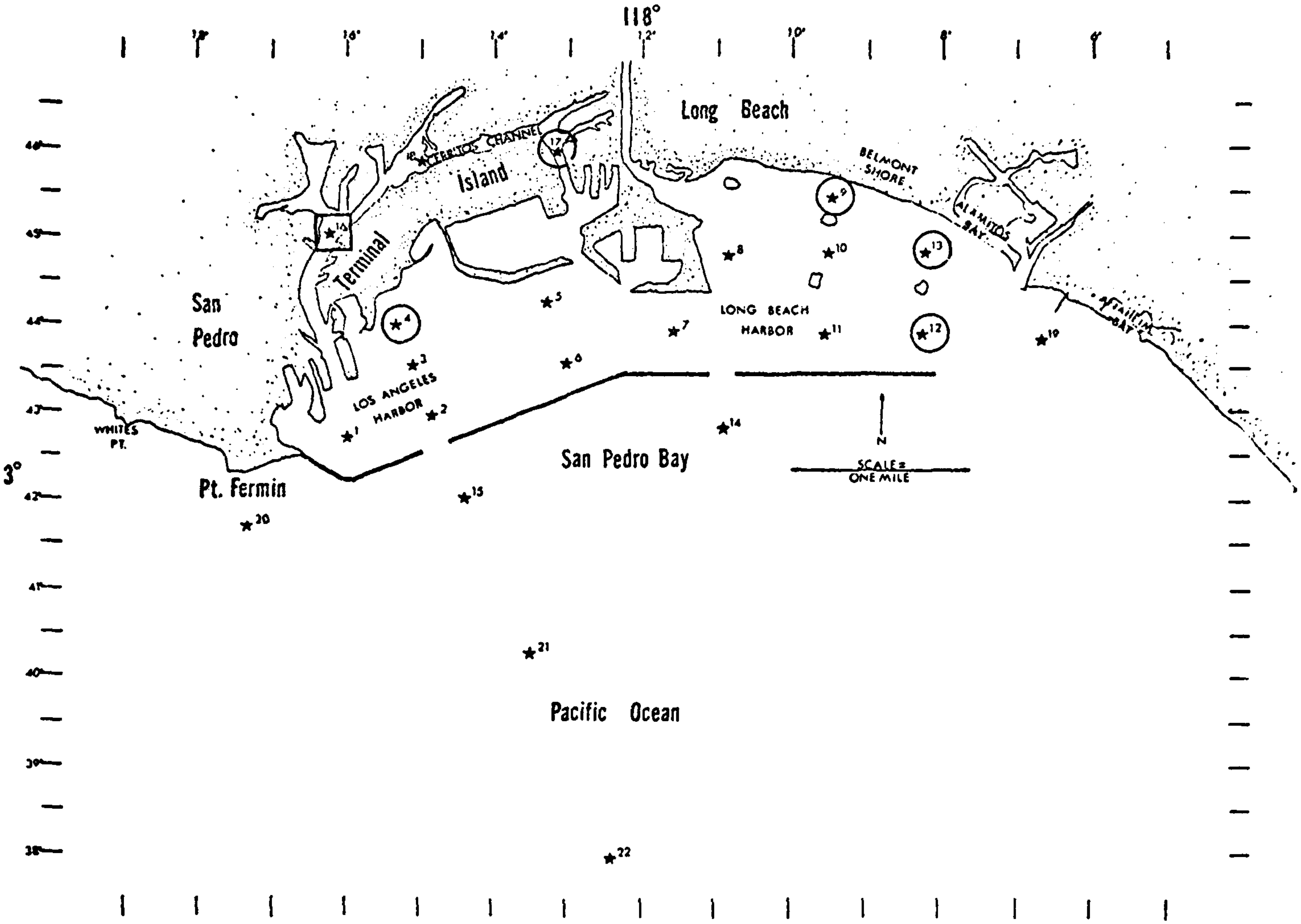


Figure 7.9 - Sciaenidae. Circled stations represent top 5 ranking stations; squared station represents the bottom ranking station.

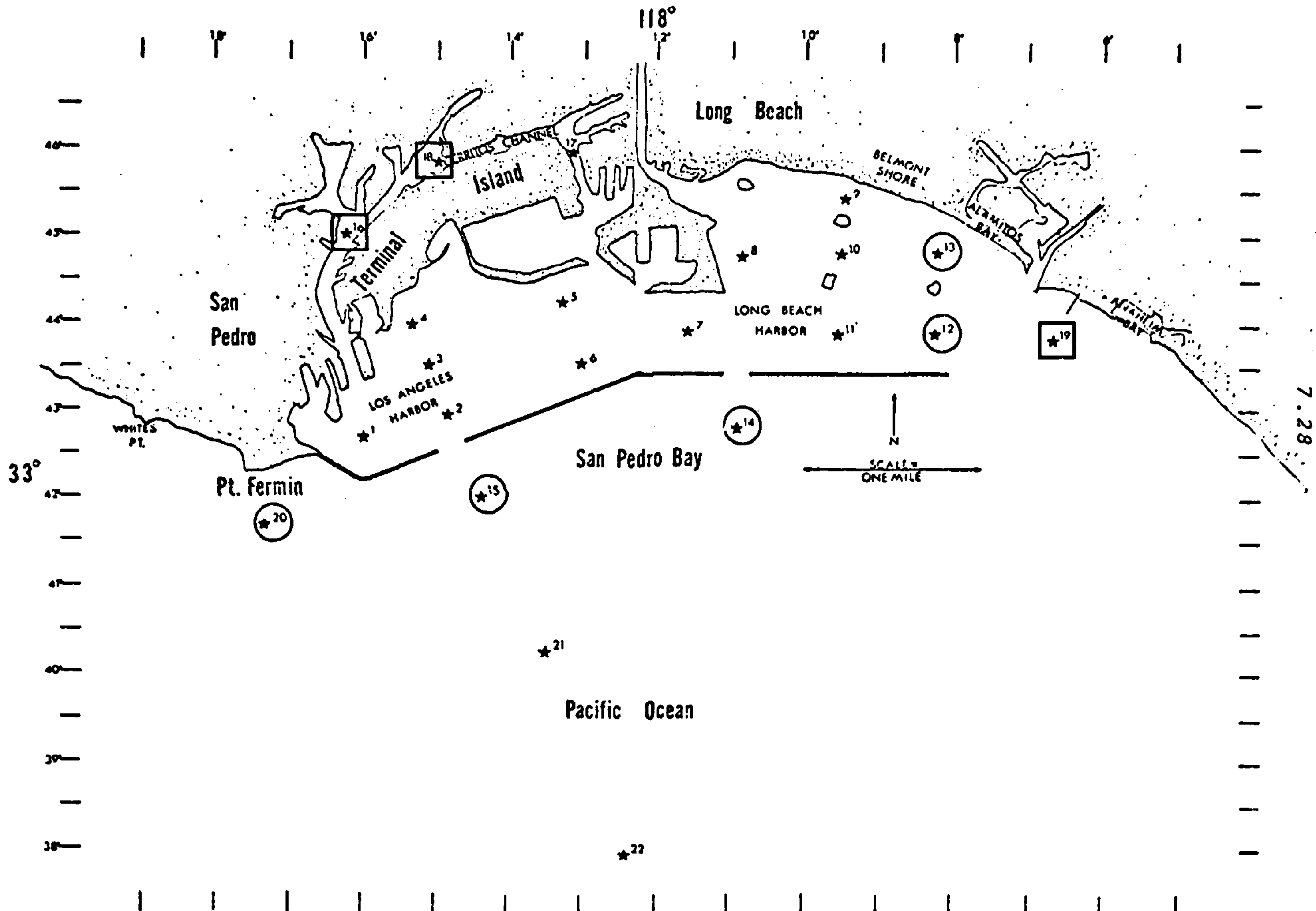


Figure 7.10 - Scorpaenidae. Circled stations represent top 5 ranking stations; squared stations represent the bottom ranking stations.

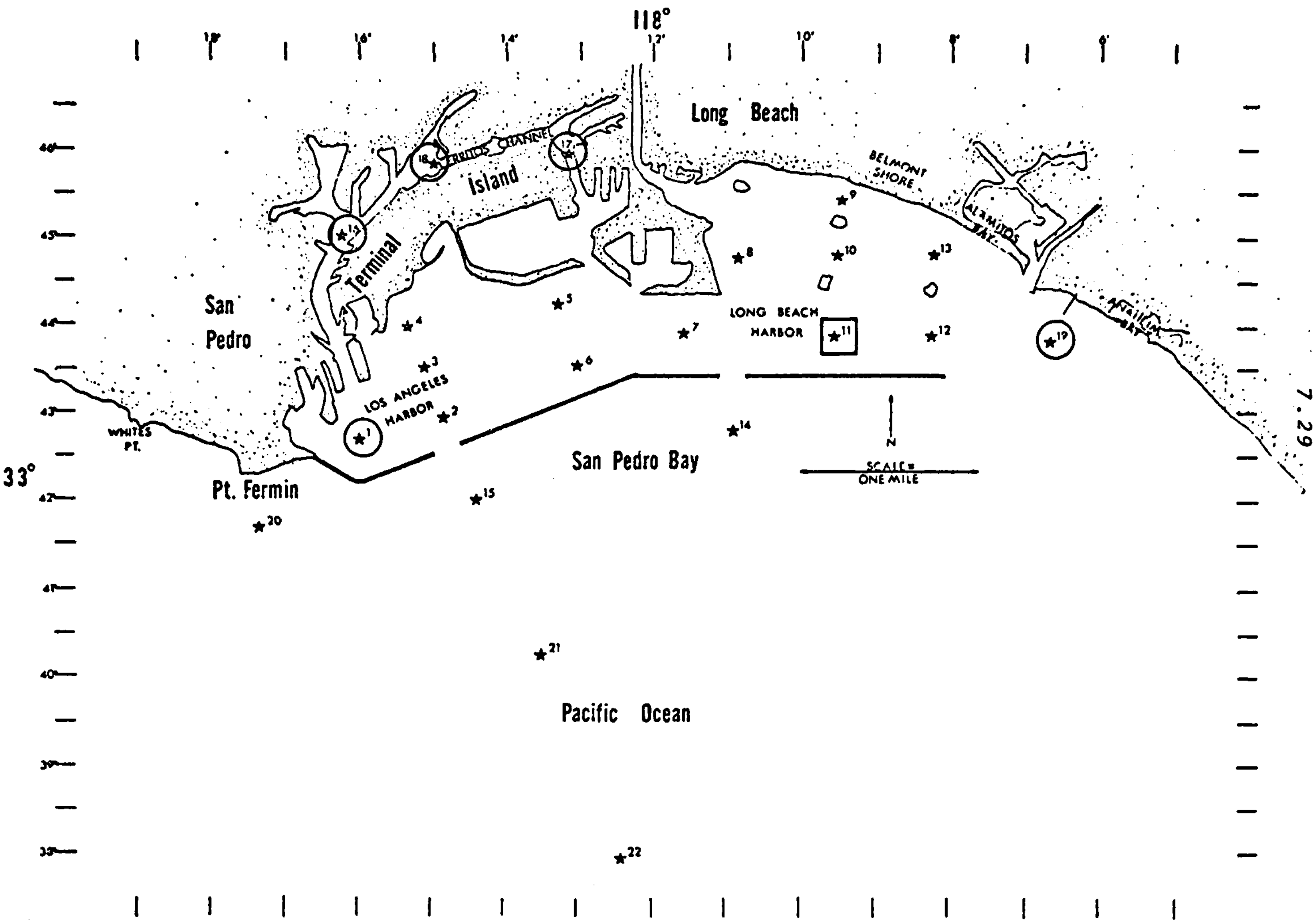


Figure 7.11 - Gobiidae. Circled stations represent top 5 ranking stations; squared station represents the bottom ranking station.

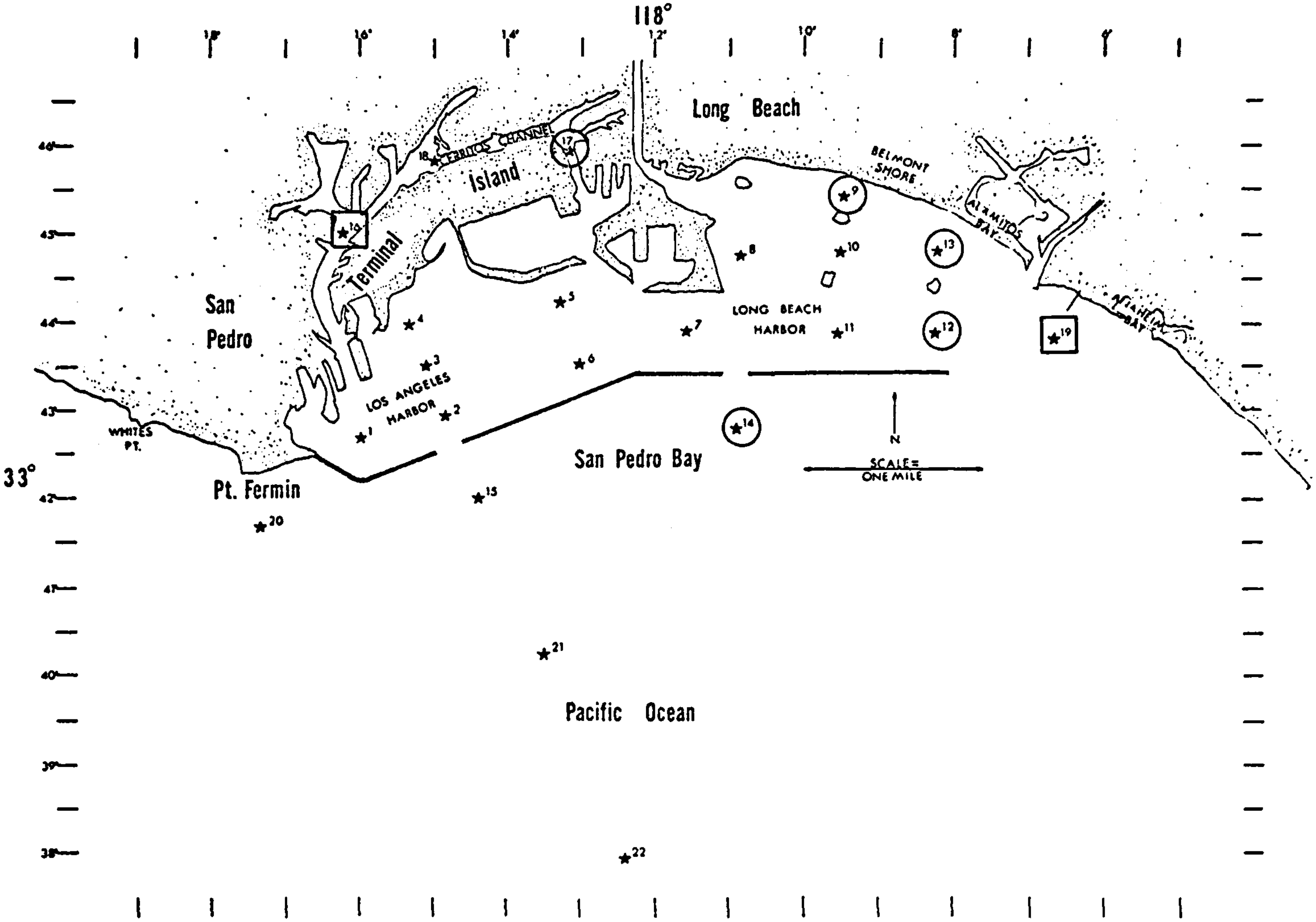


Figure 7.12 - Pleuronectidae. Circled stations represent top 5 ranking stations; squared station represents the bottom ranking station.

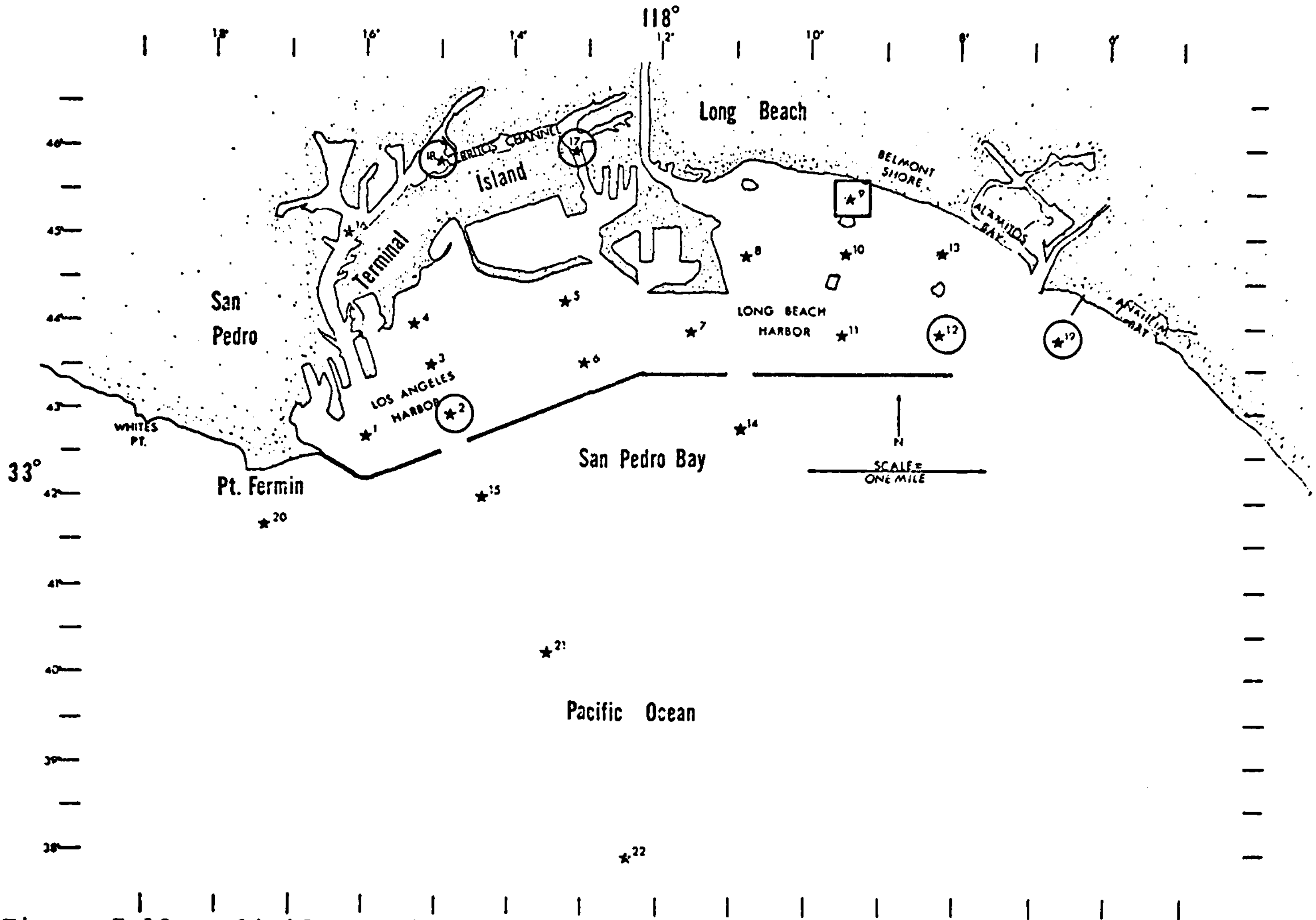


Figure 7.13 - Clinidae. Circled stations represent top 5 ranking stations; squared station represents the bottom ranking station.

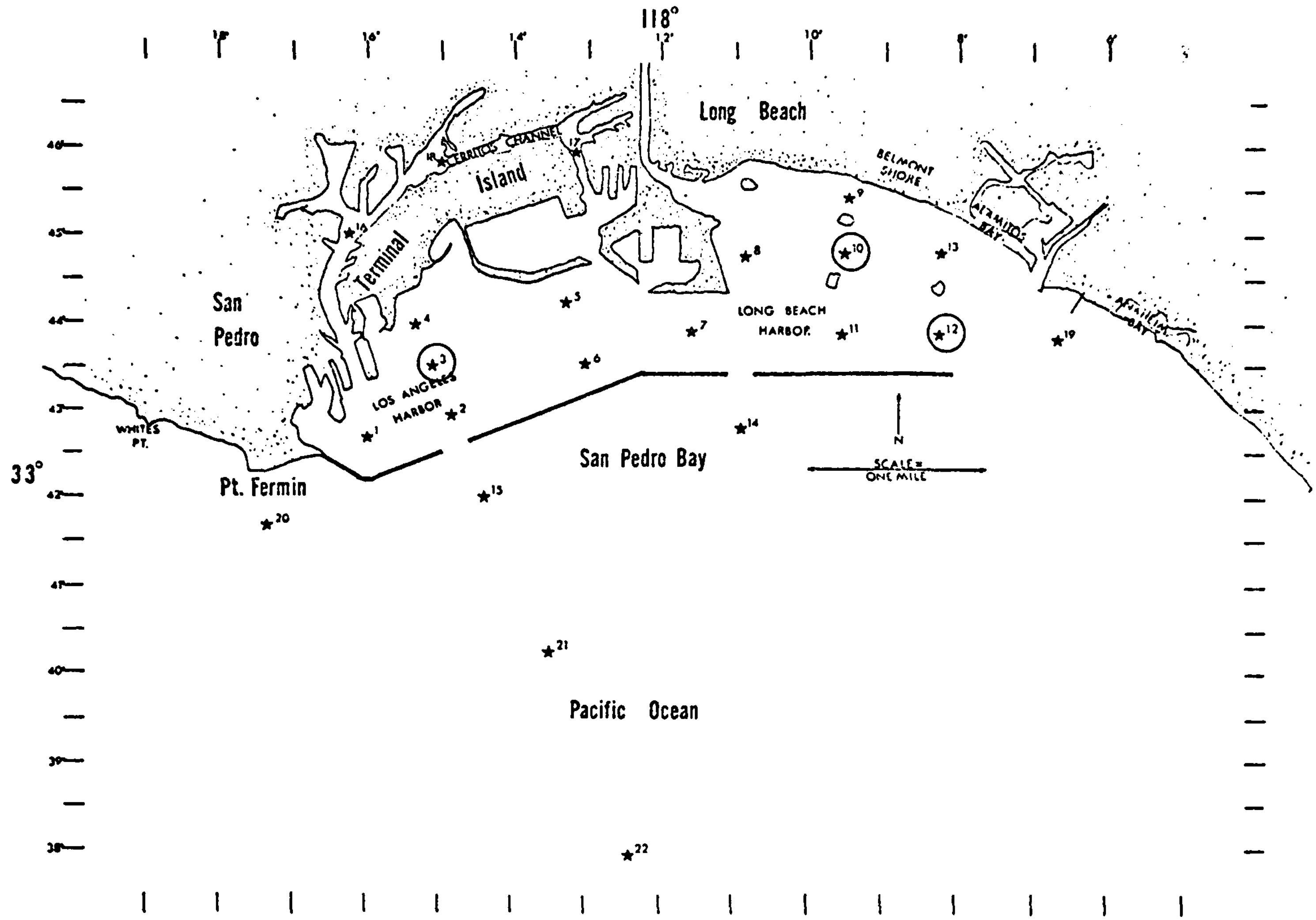


Figure 7.14 - Pomacentridae. Circled stations represent top ranking stations.

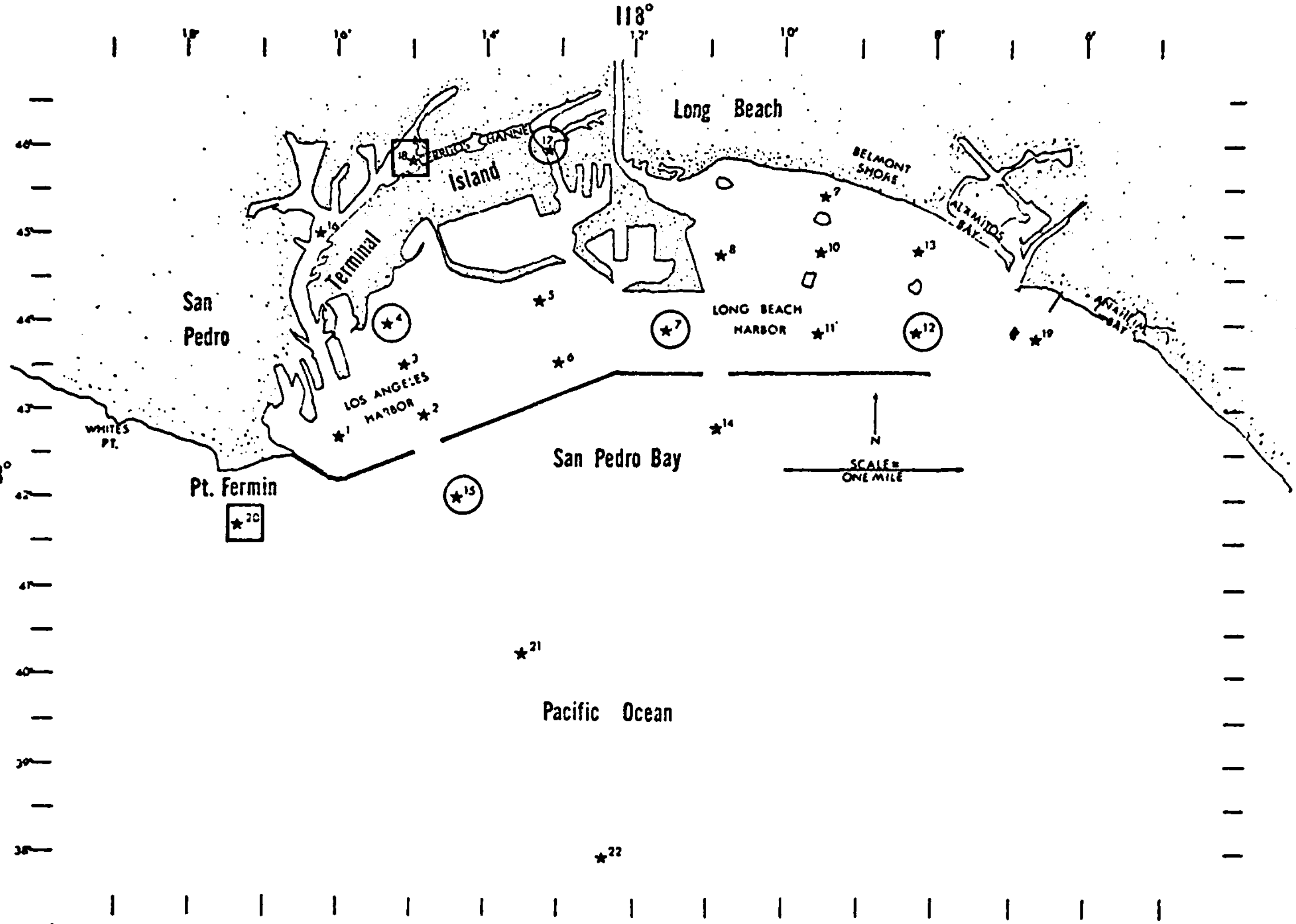


Figure 7.15 - Cottidae. Circled stations represent top 5 ranking stations; squared station represents the bottom ranking station.

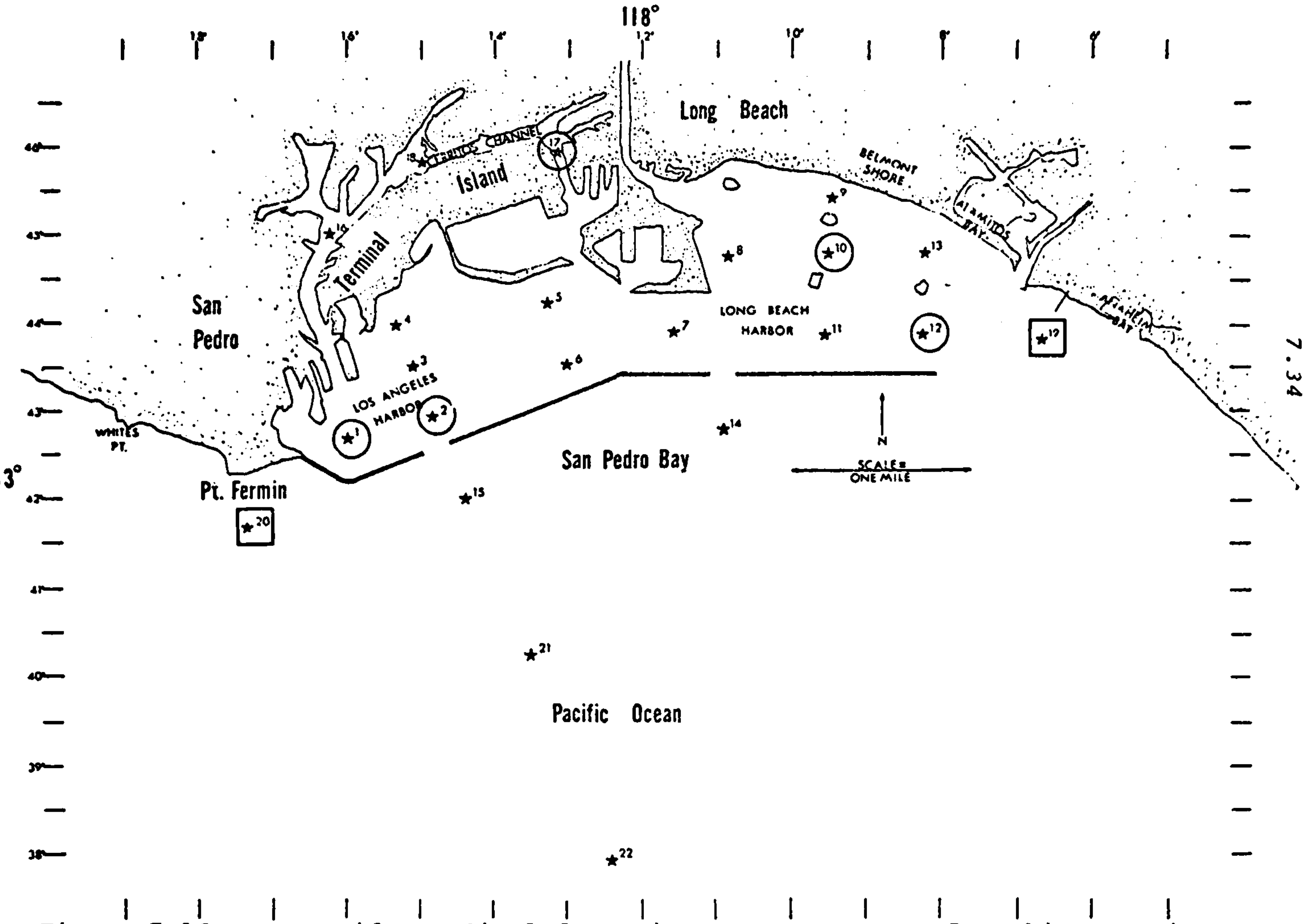


Figure 7.16 - Serranidae. Circled stations represent top 5 ranking stations; squared stations represent the bottom ranking stations.

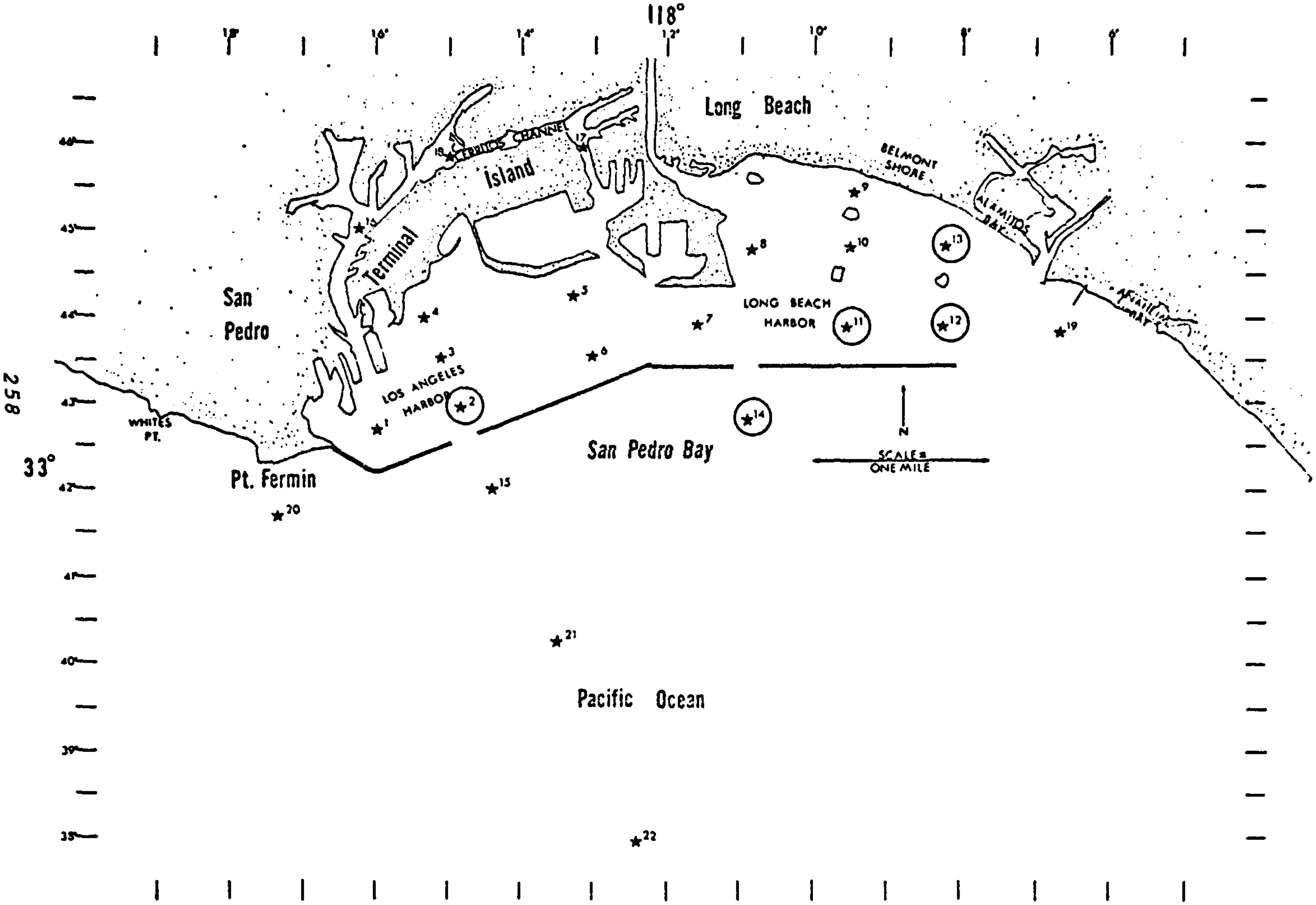


Figure 7.17 - Bothidae. Circled stations represent top 5 ranking stations.

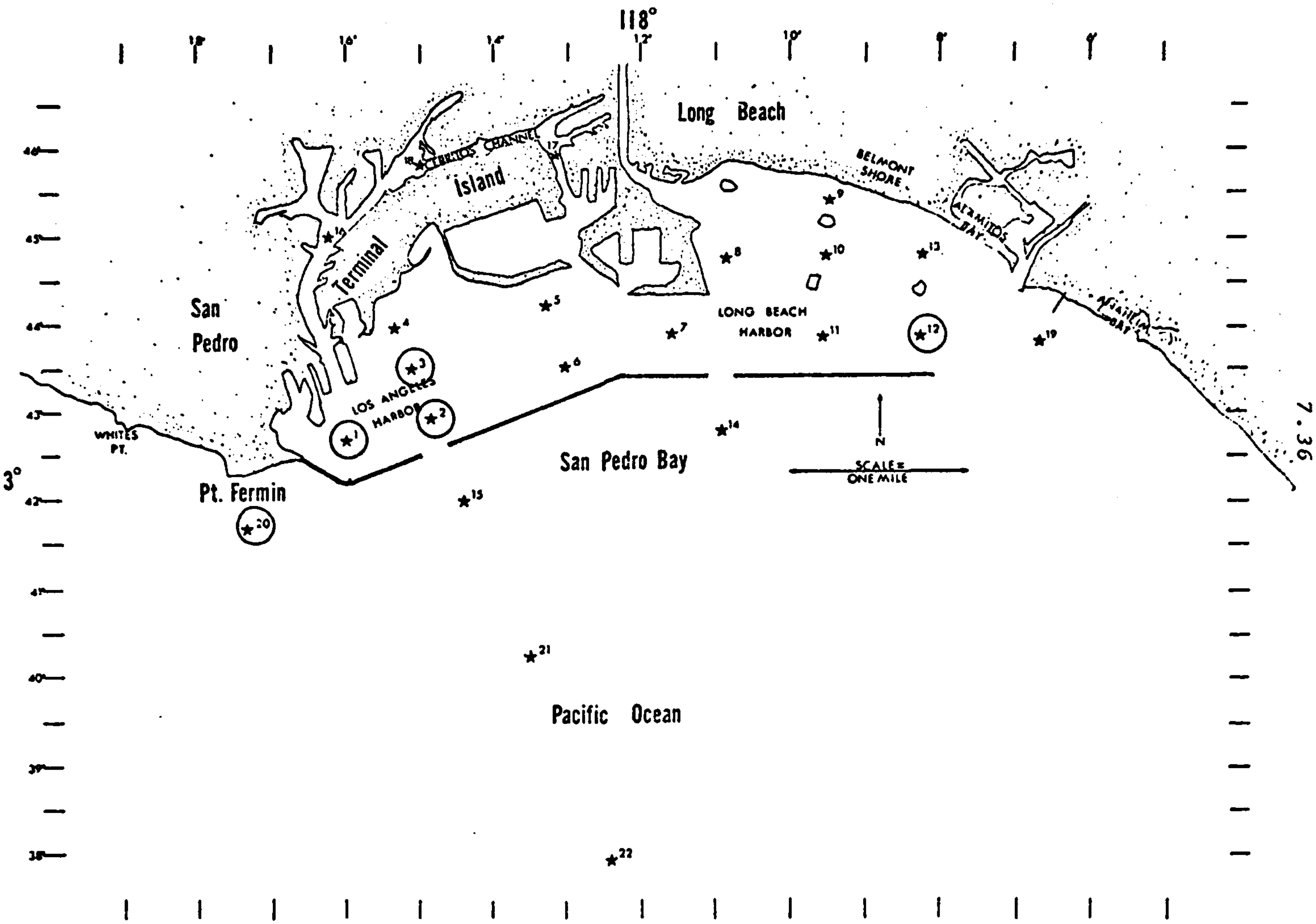


Figure 7.18 - Labridae. Circled stations represent top 5 ranking stations.

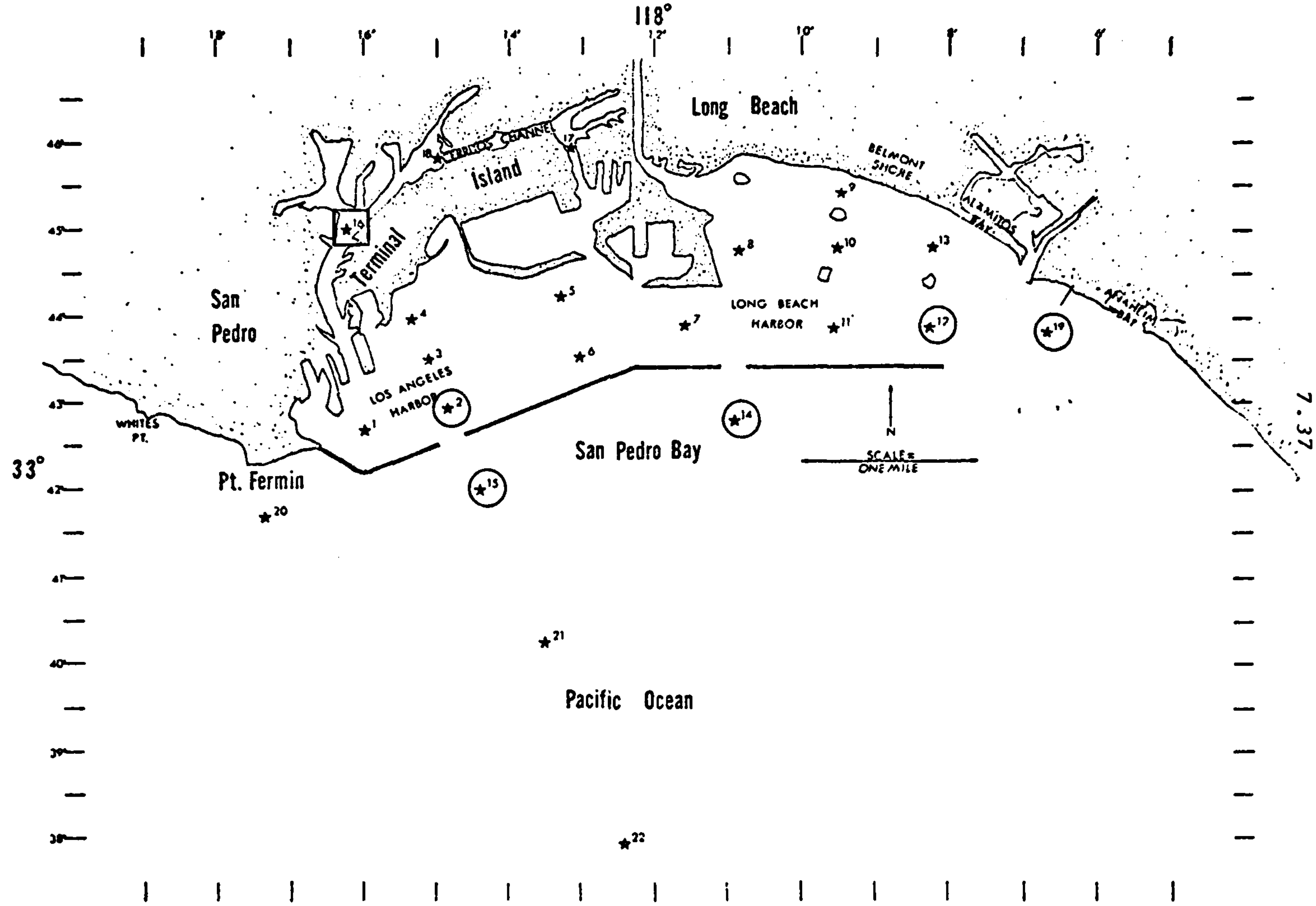


Figure 7.19 - Unidentified eggs. Circled stations represent top 5 ranking stations; squared station represents the bottom ranking station.

THE ANCHOVY IN THE LOS ANGELES HARBOR

The northern anchovy, *Engraulis mordax*, is a small schooling fish of exceptional importance in the trophic relationships of marine life in the harbor and in waters off southern California.

Commercial anchovy fishing is not permitted in the Los Angeles Harbor, but takes place off the coast. The season and catch limits are determined by the California Department of Fish and Game; the catch is used for reduction as fish meal. It is unfortunate that the season coincides in part with the late fall eutrophic conditions in which processing plant effluents are added to waters stressed by seasonal thermal turnover, stirring by high tides, storms and Santa Ana winds and Red Tide blooms. These conditions also are significant to decisions on extensive fill in the harbor with reduced circulation.

The bait fishery in the harbor is extensive, but bait catches there since 1972 have been reduced by about 50%, due apparently to a drop in demand. Although the bait fishery has been reputed to provide 50-98% of the live bait for the sport fishing industry, the decrease in demand has not been explained. Bait is also caught in quantity in open waters along the coast, and at times the harbor bait boats have been moved to the inner harbor because of the inexplicable movements of the anchovy populations. This tends to negate the supposition that anchovies will not school within 2000 feet of a land mass. The source in the outer harbor is not totally predictable; it is clear, however, that a large population of juveniles is generally found in the vicinity.

Brewer (1973) reviewed the literature on the anchovy, and carried out experimental investigations on the effects of temperature on the development of *E. mordax* (Brewer, 1974). For the Corps of Engineers, Brewer (1975) studied the entire biology and fishery in San Pedro Bay, including tabulations on bait catch, and the distribution of eggs and of juveniles in the harbor and adjacent waters. (see also Brewer, 1976).

In summary, Brewer presents the following observations in regard to the proposed interim project and the master plan:

1. The anchovy is a key component of the harbor's ecology as a major consumer of zooplankton and as an important forage item in the diets of a variety of invertebrates, fishes, birds and mammals.

2. The inshore environment off southern California, including the harbor, is an important nursery ground for juvenile anchovies. The biomass of mature, reproducing anchovies is concentrated offshore; however, spawning is at times heavy within and just outside the harbor.

3. There is extensive interchange of fish from inshore waters, including the harbor, and offshore waters, as well as movements of fish north and south along the coast. No separate stock of anchovies occurs in the harbor.

4. No reliable methods are available to assess the average biomass of juvenile anchovies in the harbor. Juvenile fish are at least as abundant within the harbor as in other inshore locations along the coast, perhaps attracted to warmer water temperatures and higher productivity in the harbor.

5. The protected nature of the harbor waters creates ideal conditions for capturing, transporting, transferring, and holding bait-fish. The behavior of the fish in the confined, shallow harbor waters makes them vulnerable to the bait fisherman's nets. A successful live-bait fishery takes advantage of these unique conditions.

6. Field and laboratory observations suggest that temporary dredging operations, creating turbidity from the resuspension of sediments, will not adversely affect anchovy development from eggs and will not exclude juvenile fish from the harbor.

7. Proposed landfill operations will cause a substantial reduction in habitat available to anchovies within the harbor and will cover a portion of the area heavily fished by bait fishermen. Anchovy biomass within the harbor can be expected to decrease approximately 50-75 percent. Proportional decreases in predatory fishes can be expected. Deepening the harbor channels may slightly offset the negative effects of landfill, but bait fishing in busy shipping channels may be impossible. Substantially increased fishing effort and operating costs can be expected by the bait fisherman.

8. Any substantial increase in tidal currents in the new harbor can be expected to have detrimental effects on bait-fish operations.

9. These effects will be strictly local, and will not affect fish abundance or availability in adjacent regions.

The incidence of other fish eggs and larvae is probably of greater importance to the trophic structure, as indicated by Stephens, et al. (1973, 1974) and Chamberlain (1973, 1974).

IMPACT OF THE MASTER PLAN ON FISH POPULATIONS OF LOS ANGELES HARBOR

Between May 24, 1972 and the present, a total of 141 trawl samples have been examined from Los Angeles Harbor. The 1972-73 data was summarized by Stephens, Terry, Subber, and Allen (1974) and compared to a previous survey of adjacent waters in San Pedro Bay (Stephens, Gardiner, and Terry, 1973). Chamberlain (1974) produced a checklist of fishes reported from all sources including historical records.

Los Angeles Harbor, particularly the outer harbor between Los Angeles and Long Beach gates, supports a very rich community of fishes. The trawl productivity is consistently high compared to most local areas. Mearns and Greene (1974) recently published a report of a comparative trawl study of Santa Monica and San Pedro Bays and Palos Verdes. This study utilized Occidental's Vantuna, and the data is relatively comparable to our harbor study. A 25 foot net with 10 minute tows was used while our harbor study has used a 16 foot net and 10 minute tows. Because of the greater net size, both diversity and numbers should be higher for Mearns' study. Further, the Mearns study was during September, 1973, a period of maximum fish numbers and diversity. It appears from Mearns' shallow water data (comparable to Los Angeles Harbor), mean abundance was 446 fish per trawl, high off Palos Verdes (854) and lower in San Pedro (248) and Santa Monica (237). The overall mean number of species (14) varies from a high of (17.5) Palos Verdes to a low of (10.3) San Pedro Bay. The abundance data can be corrected for trawling area and standardized as fish/m^2. Table 7.4 presents a comparison of Los Angeles Harbor vs. the Mearns and Green samples.

The corrected data is of special interest. The total Los Angeles Harbor average, 14.69 fish/100m^2, is about twice as high as the summed outside data (7.60). Interestingly, if only the data for the month of September (1973-74) from the harbor is utilized to compare directly with the outside data (September, 1973), the harbor average is almost six times that of the outer coast.

Abundance and richness varies considerably by month and year. Figures 7.20-21 present marked changes in abundance and richness (number of species/trawl) within the harbor (1972-75). The level of abundance drops in the fall and is apparently low in the winter, increasing to maximum population

Table 7.4. Comparison between Harbor Trawls and Bay Trawls

Location	Date(s)	Depths	Mean No. Fish /Trawl	Mean No. Species Trawl	Corrected No. fish /100 m^2	No. Trawls	Net Size
Santa Monica Bay	9/24/73	20-28 m	237.3	14.0	4.04	3	25'
Palos Verdes	9/25/73	26-30 m	854.0	17.6	14.52	3	25'
San Pedro Bay	9/26/73	24-26 m	248.0	10.3	4.22	3	25'
TOTAL ABOVE	-------	20-30 m	446.6	14.0	7.60	9	25'
L. A. Harbor (all)	1972-73	10-30 m	738.5	10.0	19.59	76	15'
L. A. Harbor (juveniles excluded)	1972-73	10-30 m	423.2	10.0	11.23	76	15'
L. A. Harbor	1973-75	10-30 m	316.7	9.6	8.40	65	15'
L. A. Harbor TOTAL	1972-75	10-30 m	554.9	9.8	14.69	141	15'
L. A. Harbor	Sept. 73-74	10-30 m	1550.0	10.0	41.0	5	15'

levels in the late spring-early summer, usually due to large numbers of young fish. The pattern of richness also follows the same trend, though 1972-73 is somewhat out of phase, and in summer 1974 we did not see maintenance of a high number of species in the harbor subsequent to the spring increase. The fact that richness and abundance both are low in the winter suggests emigration from the harbor. This agrees with the observed nursery function (utilization of harbor waters for growth of postlarval and juvenile states). Many species, i.e., rockfishes (*Sebastes*), anchovies (*Engraulis*), surf-perch (emboitocids), basses (*Serranoides*), etc., are most abundant in the harbor as juveniles.

Table 7.5 presents the relative abundance of the 8 most common species of fish within Los Angeles Harbor over the three-year period of the study. The dominant species within the harbor is the white croaker, *Genyonemus lineatus*, which makes up over 50% of the trawl catch. The remaining 7 species are much less abundant. *Engraulis mordax*, the anchovy, ranks number 2 overall. This species is relatively rare in most trawl samples during most of the year but appears in large numbers during late summer and early fall each year. *Symphurus atricaudus* and *Citharichthys stigmaeus*, two small flatfishes, are the most regularly occurring species within the harbor and rank third and fourth, respectively, in abundance.

Total abundance of fishes in the harbor has dropped relatively sharply in the last year and a half. In a comparable number of trawls (65 vs. 76) we could have expected, based on the 1972-73 catch record, about 48,000 fish in our 1973-75

Table 7.5. Number and percent composition of eight most abundant species in Los Angeles Harbor

	1973-5	1972-3	Total 1972-5	Total %
Genyonemus lineatus	11,976	30,184	42,160	56.0
Symphurus atricaudus	3,077	5,102	8,179	10.9
Citharichthys stigmaeus	2,558	3,723	6,281	8.3
Phanerodon furcatus	854	2,111	2,965	3.9
Seriphus politus	355	2,172	2,577	3.4
Pleuronichthys verticalis	339	283	622	0.8
Engraulis mordax	310	9,871	10,181	13.5
Cymatogaster aggregata	170	2,148	2,318	3.1
TOTAL	19,639 N=76	55,594 N=68	75,283 N=141	100.0

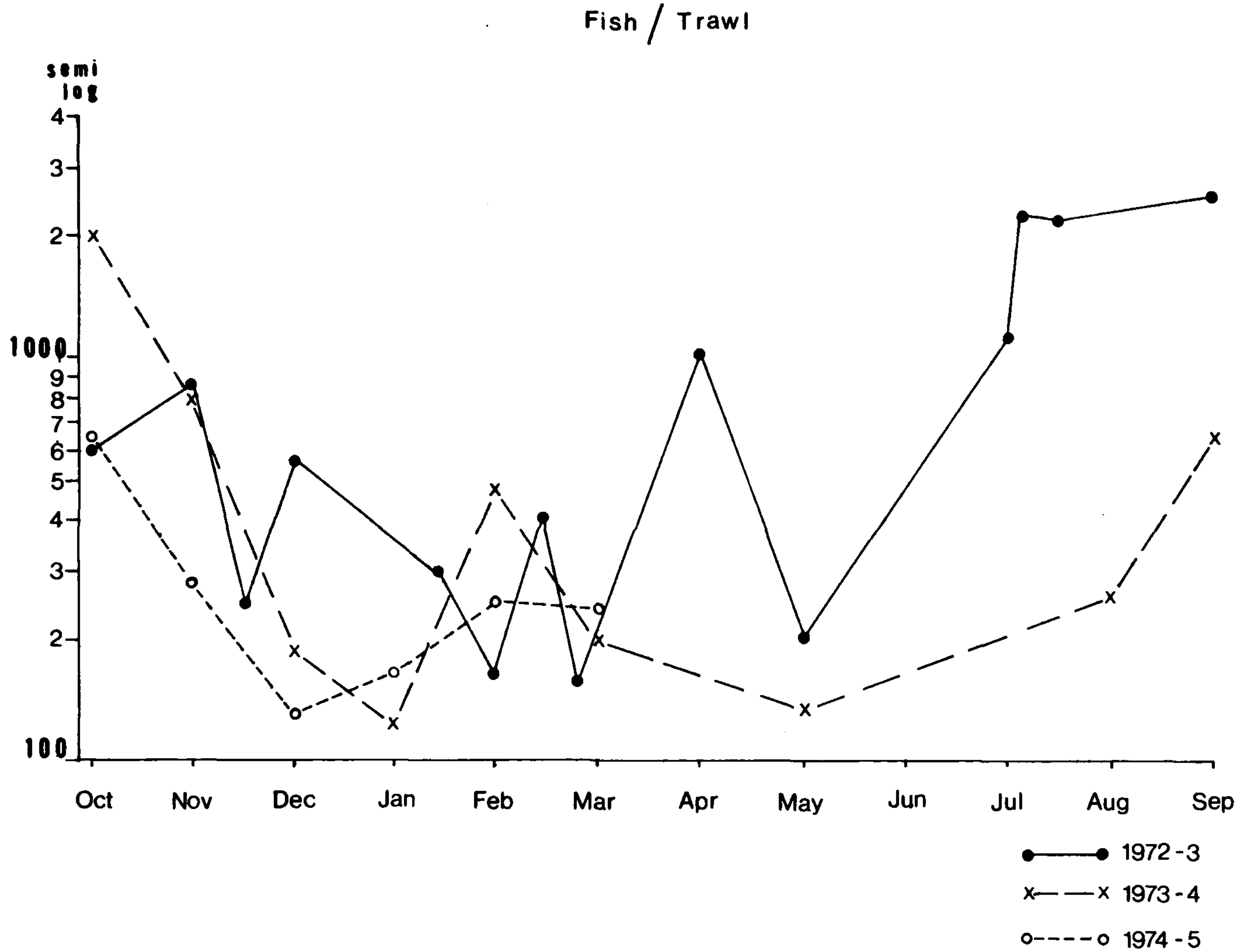


Figure 7.20. Numbers (semi-log) of Fish per Trawl 1972-1974

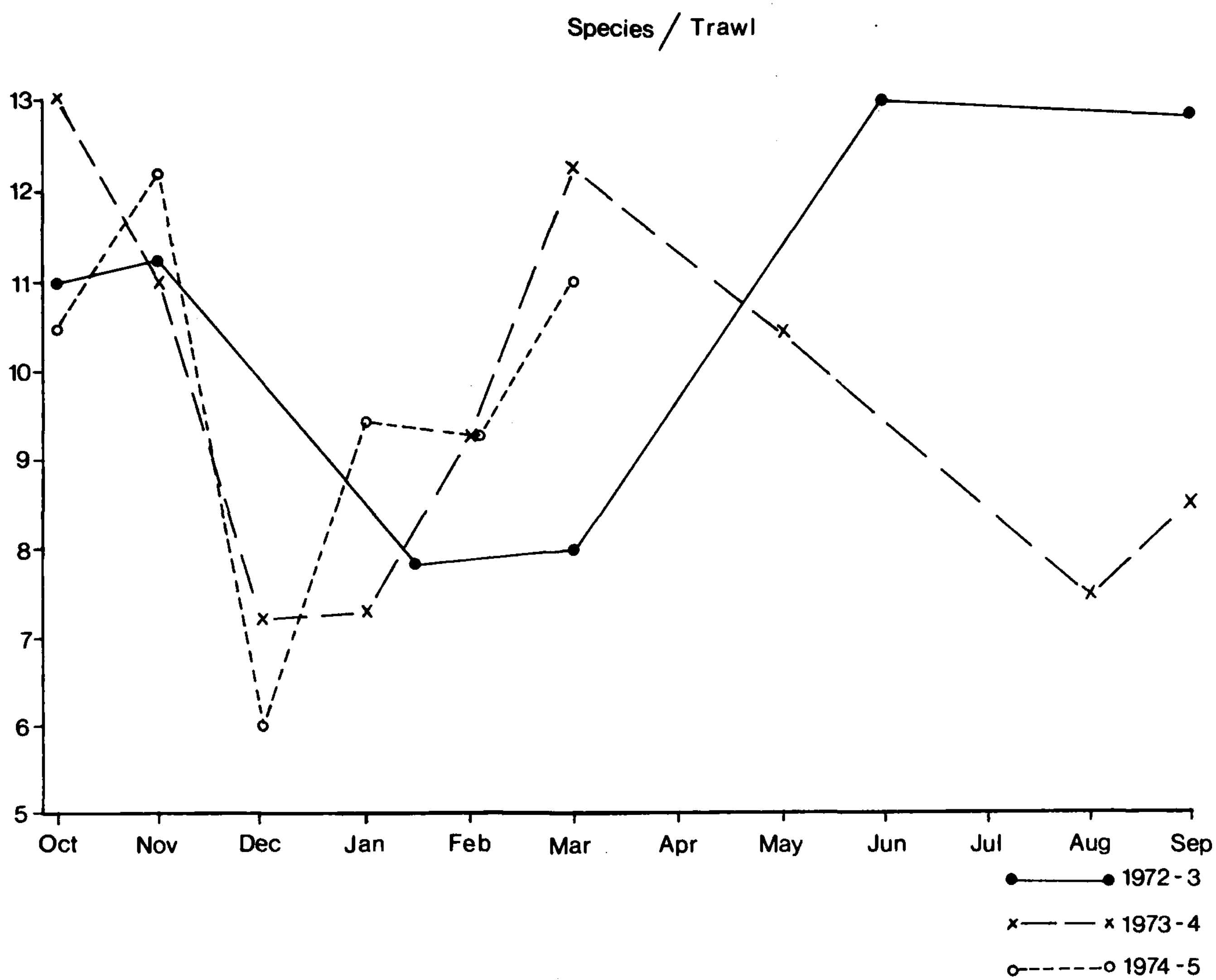


Figure 7.21. Number of Species per Trawl 1972-1974

sample. Our actual catch of 19,639 fish represents only about 40% of this expected number. If the difference by species of the 1972-73 and 1973-75 catches is examined, there is a marked decrease in abundance of all species except *Pleuronichithys*.

Interestingly, this decrease in abundance was noted in all trawling studies in southern California and probably was part of a normal cyclical fluctuation in abundance. A few species showed significant increases in abundance in 1973-75. *Synodus lucioceps* was quite abundant through March of 1974, while the halibut *Paralichthys californica* was five times as abundant in the 1973-75 period as in 1972-73.

Differences in fish abundance throughout the harbor followed the patterns described in 1974 (Stephens et al.). The most productive stations include the area around Fisn Harbor and the Navy mole and extending towards the Long Beach Gate. This area is extremely rich in croakers and halibut. The area along the middle breakwater is the most diverse and includes the highest numbers of juvenile rockfishes, while the area between the Angels Gate and bordered by the Fish Harbor zone is richest in flatfishes. Generally, the croaker area also includes Cerritos channel but productivity is much lower in this region, the majority of the important species occupying the area of the outer harbor. For detailed information on fish distributions within the harbor refer to Stephens, et al. (1974).

Ninety of the 140 trawls in Los Angeles Harbor can be assigned to specific stations as outlined by Chamberlain (1973) and Stephens, et al. (1974). These 90 stations have been through preliminary analyses by the University of Southern California Computer Center. If only species that occurred in 20 percent or more of the trawls are included, *Genyonemus* is the most abundant, averaging 416 fish/trawl; followed by *Engraulis mordax* (northern anchovy), 157; *Symphurus atricauda* (tongue sole), 68; *Citharichthys stigmaeus* (speckled sand-dab), 62; *Seriphus politus* (queenfish), 33; *Phanerodon furcatus* (white perch), 32; and *Cymatogaster aggregata* (shiner perch), 30. The next most abundant species is less than one-third as numerous as *Cymatogaster*. If regularity of occurrence (fidelity) is used rather than abundance, the order is reversed, i.e. *Symphurus*, *Phanerodon*, *Cymatogaster*, *Genyonemus*, *Citharichthys*, *Seriphus*, and *Engraulis* actually ranks ninth. These data do not differ significantly from our (1974) results. The computer has also given us a preliminary analysis of seasonality and co-association, but it is presently too early to suggest how these breakdowns differ, if at all, from our original analysis (ibid.).

Recommendations

The following statement, by J.S.Stephens, Jr., indicates anticipated impacts of the Master Plans:

"The fish populations of Los Angeles Harbor are very rich. The richness of the harbor ichthyofauna appears to be the result of the protected nature of the waters, the richness of food, or the high productivity of these surface waters due partially to nutrient enrichment, and the diversity of bottom types (i.e., mud, sand, rock, level of organic deposits, etc.). The present structure of the outer harbor insures adequate circulation and there are, therefore, few limitations besides space and nutrient levels on fish production."

"The suggested Master Plan for outer Los Angeles Harbor should result in a drastic change in fish populations. The combination of dredging and filling should destroy all existing ichthyofauna. The richest soft bottom ichthyofauna of California will be eliminated. This fauna will succeed itself after construction is completed, but should develop only along the lines of the present Cerritos Channel ichthyofauna which is low in species and numbers. I would suggest that no species are liable to extinction from this modification, but by destroying the important nursery function of the harbor many local species may show population decreases. Further, the important recreational shore and skiff fishing and the bait industry of the harbor will be eliminated. I recommend either a considerably less extensive restructuring of the outer harbor or, better yet, external mooring facilities (monobuoys). The interim plan probably represents the least impact potential on the fish populations because the main channel is not an important habitat in the harbor."

Short term impacts of dredging include possible damage to fish in the immediate area due to irritation of respiratory surfaces and anoxia due to depletion of dissolved oxygen from the oxygen demand of the resuspended sediments. Some fish are attracted to areas of dredging activity to feed, and might ingest quantities of pollutants above normal levels. This might make the fish hazardous to regular consumers for some period.

In addition to the long term effects mentioned by Stephens, the reduced fish population might cause an increase in eutrophication due to greatly reduced grazing on phytoplankton.

LITERATURE CITED

Ahlstrom, E.H. 1959. Vertical distribution of pelagic fish eggs and larvae off California and Baja California. U.S.Fish and Wild. Serv., Fish. Bull. 60(191):107-146.

____________. 1965. Kinds and abundance of fishes in the California current region based on egg and larval surveys. Calif. Coop. Oceanic Fish. Invest. Prog. Rept. 10:31-52.

____________. 1967. Co-occurrence of sardine and anchovy larvae in the California current region of California and Baja California. Calif. Coop. Oceanic Fish. Invest. Prog. Rept. 11:117-135.

____________. 1968. What might be gained from an oceanwide survey of fish eggs and larvae in various seasons. Calif. Coop. Oceanic Fish. Invest. Rept. 12:64-67.

____________. 1969. Mesopelagic and bathypelagic fishes in the California current region. Calif. Coop. Oceanic Fish. Invest. Rept. 13:39-44.

Bailey, R.M., J.E.Fitch, E.S.Herald, E.A.Lachner, C.C.Lindsey, C.R.Robbins, and W.B.Scott. 1970. A list of common and scientific names of fishes from the United States and Canada. 3rd ed. Amer. Fish. Soc., Special Publ. No. 6, Washington, D.C. 150 p.

Brewer, G.D. 1973. Annotated bibliography of the northern anchovy, *Engraulis mordax* Girard. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part II, Biological Investigations. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. 237 p.

___________. 1974. Preliminary observations of the lower minimum temperature requirements of the northern anchovy. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 3. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 21-43.

___________. 1975. The biology and fishery of the northern anchovy in San Pedro Bay. Potential impact of proposed dredging and landfill. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 8. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 23-44.

___________. 1976. Resuspended sediment elutriate studies on the northern anchovy. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 11. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 15-32.

Carlisle, J.G., Jr. 1969. Results of a six-year trawl study in an area of heavy waste discharge: Santa Monica Bay, California. Calif. Fish and Game 55:26-46.

Chamberlain, D.W. 1973. Results of fourteen benthic trawls conducted in the outer Los Angeles-Long Beach Harbor, California, May 24, 1972. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part II, Biological Investigations. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 107-145.

________________. 1974. A checklist of fishes from Los Angeles-Long Beach Harbors. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 4. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 43-78.

________________. 1976. Effects of the Los Angeles Harbor sediment elutriate on the California killifish, *Fundulus parvipinnis* and white croaker, *Genyonemus lineatus*. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 11. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 33-47.

de Vlaming, V.L. 1972. Environmental control of teleost reproductive cycles: A brief review. J.Fish. Biol. 4:131-140.

Ebling, et al. 1971. Santa Barbara oil spill: Short term analysis of macroplankton and fish. Office of Water Quality Research, Environmental Protection Agency, U.S.Govt. Printing Office. p. 37-68.

Lane, E.D. 1971. Studies of the biology of the fishes utilizing Anaheim Bay, their population structure, food utilization and fish production in the area. Abstracts of the Second Coastal and Shallow Water Research Conference. Los Angeles, Calif. 128 pp.

McHugh, J.L. 1966. Management of estuarine fisheries. Am.Fish. Soc., Spec. Publ. 3:133-143.

____________. 1967. Estuarine nekton. In Estuaries. G.H.Lauff, ed. Am. Assoc. Adv. Sci. Publ. 83, p. 581-620.

Mearns, A.J., M.J.Allen. 1973. A checklist of inshore demersal fishes from southern and central California. Southern Calif. Coastal Water Research Project. 10 p.

Mearns, A., J.Allen, and M.Sherwood. 1973. An otter trawl survey off the Palos Verdes Peninsula and Santa Catalina Island, May-June, 1972. Southern California Coastal Water Reserach Project. TM 204: 21 p.

Mearns, A., J.Allen, and M.Sherwood. 1974. An otter trawl survey of Santa Monica Bay, May-June, 1972. Southern California Coastal Water Research Project. 24 pp.

__________________________________ and R.Gammon. 1973. An otter trawl survey off the Palos Verdes Peninsula and Santa Catalina Island, November-December, 1972. Southern California Coastal Water Reserach Project. TM 205: 25 pp.

Mearns, A., and Greene. 1974. A comparative survey of three areas of heavy waste discharge. Southern California Coastal Water Research Project. TM 215.

Miller, D.J. and R.N.Lea. 1972. Guide to the coastal marine fishes of California. Calif. Dept. Fish and Game Bull. 157. 235 p.

Moser, H.G. 1967. Reproduction and development of *Sebastodes paucispinis* and comparison with other rock-fishes off southern California. Copeia 1967:773-797.

_________ and E.H.Ahlstrom. 1970. Development of lanternfishes (Family Myctophidae) in the California current. Part I. Species with narrow-edged larvae. Bull. Los Angeles County Mus. Nat. Hist. 7:1-145.

Phillips, L., C.Terry, and J.Stephens, Jr. 1972. Status of the white croaker (*Genyonemus lineatus*) in the San Pedro Bay region. A preliminary report to the Southern California Coastal Water Research Project. SCCWRP TP 109: 40 p.

Reish, D.J. 1958. Marine life of Alamitos Bay. Seaside Printing Co., Long Beach, California. p. 64-67.

Richardson, S.L. 1973. Abundance and distribution of larval fishes in waters off Oregon, May-October, 1969, with special emphasis on the northern anchovy, *Engraulis mordax*. Fish. Bull. 71(3):697-712.

SCCWRP. 1973. Annual Report. Southern Calif. Coast. Wat. Res.Proj.

SCCWRP. 1974. Annual Report. Southern Calif. Coast. Wat. Res.Proj.

Stephens, J.S., Jr., D.Gardiner, and C.Terry. 1973. The demersal fish populations of San Pedro Bay. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 2. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 148-166.

_____________, C.Terry and M.J.Allen. 1974. Abundance, distribution, seasonality, and productivity of the fish populations in Los Angeles Harbor, 1972-73. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri. eds. Part 4. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 1-42.

Ulrey, A.B., and P.O.Greeley. 1928. A list of marine fishes (Teleostei) of southern California with their distribution. Bull. So. Calif. Acad. Sci. 27(1):1-53.

U.S.Army Corps of Engineers District, Los Angeles. MS, 1972. Los Angeles-Long Beach Harbors, L.A.County, California. Environmental Statement. 57 p.

Young, P.H. 1964. Some effects of sewer effluent on marine life. Calif. Fish and Game 50(1):33-41.

APPENDIX 1. CHECKLIST OF FISHES

PHYLUM CHORDATA

CLASS CHONDRICHTHYS - CARTILAGENOUS FISHES

Order Heterodontiformes

FAMILY HETERODONTIDAE - Bullhead Sharks

Hornshark . . . . *Heterodontus francisci* (Girard)
Gulf of California to Monterey Bay. Shallow to 492 feet. Los Angeles-Long Beach Harbor: S3.

Order Squaliformes

FAMILY CARCHARHINIDAE - Requiem Sharks

Soupfin shark. . . *Galeorhinus zygopterus* Jordan & Gilbert
Chile and Peru to Northern British Columbia, but not in the tropics. Near water surface. Los Angeles-Long Beach Harbor: S4.

Grey smoothhound. . . . . *Mustelus californicus* Gill
Mazatlan, Mexico, to Cape Mendocino, California. Shallow to 150 feet. Los Angeles-Long Beach Harbor: BS, HLA, Common.

Brown smoothhound . . . . *Mustelus henlei* (Gill)
Gulf of California to Humboldt Bay, California. Shallow. Los Angeles-Long Beach Harbor: HLA, S1.

Leopard shark. . . . .*Triakis semifasciata* Girard
Mazatlan, Mexico, Gulf of California to Oregon. Bays and beaches. Los Angeles-Long Beach Harbor: BS, S3.

FAMILY SQUALIDAE - Dogfish Sharks

Spiny dogfish. . . . .*Squalus acanthias* Linnaeus
Temperate and Subtropical Atlantic and Pacific, Chile, Baja California to Alaska, Japan. Shallow to 1200 feet. Los Angeles-Long Beach Harbor: T8, T11.

FAMILY SQUATINIDAE - Angel Sharks

Pacific angel shark . . . . . .*Squatina californica* Ayres
Chile, Gulf of California to South East Alaska. Shallow water. Los Angeles-Long Beach Harbor: S4.

Order Rajiformes (Batoidei)

FAMILY PLATYRHINIDAE - Thornbacks*

Thornback. . *Platyrhinoidis triseriata* (Jordan & Gilbert)
Baja California to San Francisco. Shallow to 150 feet. Los Angeles-Long Beach Harbor: BS, S1.

FAMILY RHINOBATIDAE - Guitarfishes

Shovelnose guitarfish . . . . *Rhinobatos productus* (Ayres)
Gulf of California to San Francisco (recent records only to Capitola). Surface to 50 feet. Los Angeles-Long Beach Harbor: BS, S1.

FAMILY TORPEDINIDAE - Electric rays

Pacific electric ray . . . . . *Torpedo californica* Ayres
Baja California to British Columbia. Shallow to 640 feet. Los Angeles-Long Beach Harbor: T7, T12, T13 (A number have been collected in other trawls but additional data is unavailable), Common.

FAMILY RAJIDAE - Skates

California skate . . . . . . *Raja inornata* Jordan & Gilbert
Baja California to Strait of Juan de Fuca. 60 to 2200 feet. Los Angeles-Long Beach Harbor: S1.

FAMILY DASYATIDIDAE* - Stingrays

Diamond stingray. . *Dasyatis dipterura* (Jordan & Gilbert)
Paita, Peru, to Kyuhuat, British Columbia. Shallow to 55 feet. Los Angeles-Long Beach Harbor: BS, S3, S4.

California butterfly ray. . . *Gymnura marmorata* (Cooper)
Peru to Point Conception. Shallow bays and beaches. Los Angeles-Long Beach Harbor: BS, S4.

Round stingray. . . . . *Urolophus halleri* Cooper
Panama Bay to Humboldt Bay. To 70 feet. Los Angeles-Long Beach Harbor: BS, S1, S3, S4.

FAMILY MYLIOBATIDAE - Eagle Rays

Bat ray . . . . *Myliobatis californica* Gill
Gulf of California to Oregon. To 150 feet. Los Angeles-Long Beach Harbor: BS, HLD, S1, S3, T3, T6, Common.

Order Chimaeriformes

FAMILY CHIMAERIDAE - Chimaeras

Ratfish. . . . . *Hydrolagus colliei* (Lay & Bennett)
Gulf of California to South East Alaska. Shallow to 1200 feet. Los Angeles-Long Beach Harbor: S4.

CLASS OSTEICHTHYS - BONY FISHES

Order Anguilliformes (Apodes & Lyomeri)

FAMILY MURAENIDAE - Morays

California moray. . . . . *Gymnothorax mordax* (Ayres)
Baja California to Point Conception. Shallow reef areas. Los Angeles-Long Beach Harbor: S1, S4, Common along inside of outer breakwaters (Ron Williamson, Univ. So. Calif., pers. comm.).

Order Clupeiformes

FAMILY CLUPEIDAE - Herrings

Pacific sardine. . . . . . *Sardinops sagax caeruleus* Jenyns
Guaymas, Mexico, to Kamchatka. Epipelagic. Los Angeles-Long Beach Harbor: BS, S3.

FAMILY ENGRAULIDIDAE - Anchovies

Deepbody anchovy. . . . . *Anchoa compressa* (Girard)
Todos Santos Bay, Baja California to Morro Bay. Bays and estuaries. Los Angeles-Long Beach Harbor: BS, S3, T8, T13, T14, T17.

Anchoveta. . . . . *Centengraulis mysticetus* (Gunther)
Sechura Bay, Peru, to Los Angeles Harbor. Los Angeles-Long Beach Harbor: Not taken, may be introduction (see Miller & Lea, 1972, p. 56).

Pacific Herring. . . .*Clupea harengus pallasi* Valenciennes
Northern Baja California to Arctic Ocean and Japan. Inshore schooling fish. Los Angeles-Long Beach Harbor: BS.

Northern Anchovy . . . .*Engraulis mordax* Girard
Cape San Lucas, Baja California to Queen Charlotte Island, British Columbia. Los Angeles-Long Beach Harbor: BS, S1, S3, T3-T16, Common.

Slough anchovy . . . . *Anchoa delicatissima* (Girard)
Magdalena Bay, Baja California to Belmont Shores, Long Beach Harbors. Estuaries and bay backwaters. Los Angeles-Long Beach Harbor: BS, T6, T8, T13.

Order Salmoniformes

FAMILY SALMONIDAE - Salmons and Trouts

Coho (Silver) salmon . . . . *Onchorynchus kisutch* (Walbaum)
Chamalu Bay, Baja California to Bering Sea to Japan. Anadromous. Los Angeles-Long Beach Harbor: S1, Rare.

Order Myctophiformes

FAMILY SYNODONTIDAE - Lizardfishes

California lizardfish. . . . . . . *Synodus lucioceps* (Ayres)
Guaymas, Mexico, to San Francisco. 5 to 150 feet. Los Angeles-Long Beach Harbor: S1, S4, T4-T7, T9, T11, T14, T16, U&G.

Order Batrachoidiformes

FAMILY BATRACHOIDIDAE - Toadfishes

Specklefin midshipman . . *Porichthys myriaster* Hubbs & Schultz
Magdalena Bay, Baja California to Point Conception, California. Shallow to 414 feet. Los Angeles-Long Beach Harbor: BS, HLA, S1, S3, S4, T2-T17, Common.

Plainfin midshipman . . . . *Porichthys notatus* Girard
Gulf of California Y Gorda Bank, Baja California to Sitka, Alaska. Surface to 1000 feet. Los Angeles-Long Beach Harbor: T5 (only one fish taken), Rare (may be seasonal), U&G.

Order Gadiformes (Anacanthini)

FAMILY GADIDAE - Codfishes

Pacific tomcod*. . . . . *Microgadus proximus* (Girard)
Santa Monica Reef to Bering Sea. 40 to 1200 feet. Los Angeles-Long Beach Harbor: S3.

FAMILY OPHIDIIDAE - Cusk-eels

Spotted cusk-eel . . . . *Chilara taylori* (Girard)
San Cristobal Bay, Baja California to Northern Oregon. 4 to 800 feet. Los Angeles-Long Beach Harbor: T5, T7, T8, T13, G14.

Basketweave cusk-eel. . . . . . . *Otophidium scrippsi* Hubbs
North of Guaymus, Mexico, to Point Arguello. Depth 9 to 230 feet. Los Angeles-Long Beach Harbor: BS.

Order Atheriniformes

FAMILY BELONIDAE - Needlefishes

California needlefish. . . . . *Strongylura exilis* (Girard)
Peru to San Francisco. Shallow to about 300 feet. Los Angeles-Long Beach Harbor: Belmont shore. Summer 1972, Beach Seine, Occidental College.

FAMILY CYPRINODONTIDAE

California killifish. . . . .*Fundulus parvipinnis* Girard
Common in Bays of Southern California. Los Angeles-Long Beach Harbor: BS,U&G.

FAMILY ATHERINIDAE - Silversides

Topsmelt. . . . .*Atherinops affinis* (Ayres)
Gulf of California to 4 mi. west of Sooke Harbor, Vancouver Island, B.C. Bays, sloughs, kelp beds. Los Angeles-Long Beach Harbor: BS, DV1, GN1, GN3, HLA, HLE, S1, S2 (dipnetted at Marina, Watchhorn Basin, SanPedro), Common.

Jacksmelt . . . .*Atherinopsis californiensis* Girard
Santa Maria Bay, Baja California to Yaquina, Oregon. Inshore, bays, Los Angeles-Long Beach Harbor: BS, HLE, S1, S2 (dipnetted at marina, Watchhorn Basin, San Pedro).

California grunion . . . .*Leuresthes tenuis* (Ayres)
Magdalena Bay to San Francisco. Surface to 60 feet. Los Angeles-Long Beach Harbor: BS, S1, S2, (taken by dipnet at Marina, Watchhorn Basin, San Pedro), S3, Common.

Order Gasterosteiformes

FAMILY SYNGNATHIDAE - Pipefishes

Kelp Pipefish. . . . . . .*Syngnathus californiensis* Storer
Santa Maria Bay, Baja California to ca. San Francisco. Kelp beds. Los Angeles-Long Beach Harbor: T8, U&G.

Pipefish. . . . .*Syngnathus* sp.
BS,S3,T6,T7,T8,T13,T16.

Order Perciformes (Percomorphi; Acanthopterygii)

FAMILY SERRANIDAE - Sea Basses

Kelp bass . . . .*Paralabrax clathratus* (Girard)
Magdalena Bay, Baja California to Columbia River. Surface to 150 feet. Los Angeles-Long Beach Harbor: BS, DV1, GN1, HLA, HLC, S1.

Spotted sand bass .*Paralabrax maculofasciatus* (Steindachner)
Mazatlan, Mexico, to Monterey, California, including Gulf of California. To 200 feet. Los Angeles-Long Beach Harbor: BS, DV1, GN1, HLA, HLB, HLC, HLD, S1, S2 (Fish Harbor, Terminal Island), T14 (only one fish taken), Common.

Barred sand bass . . . .*Paralabrax nubelifer* (Girard)
Magdalena Bay, Baja California, to Santa Cruz, California. Shallow to 600 feet. Los Angeles-Long Beach Harbor: BS, DV1, GN1, HLC, S1, S3, S4, T12, T17.

Giant sea bass. . . . .*Stereolepis gigas* Ayres
Gulf of California to Humboldt Bay. 18 to 100 feet. Los Angeles-Long Beach Harbor: S4.

FAMILY BRANCHIOSTEGIDAE - Tile fishes

Ocean whitefish. . . . . .*Caulolatilus princeps* (Jenyns)
Peru to British Columbia. Surface to 300 feet. Los Angeles-Long Beach Harbor: S3, S4.

FAMILY CARANGIDAE - Jacks and Pompanos

Jack Mackerel. . . . .*Trachurus symmetricus* (Ayres)
Magdalena Bay, Baja California to South East Alaska. Surface to 150 feet. Los Angeles-Long Beach Harbor: S1, S3.

FAMILY POMADASYIDAE - Grunts

Sargo. . . . .*Anisotremus davidsoni* (Steindachner)
Magdalena Bay, Baja California to Santa Cruz, California. Surface to 130 feet. Los Angeles-Long Beach Harbor: BS, HLA, HLE, S3, S4, Common, U.&G.

Salema. . . . . .*Xenistius californiensis* (Steindachner)
Peru to Monterey Bay, Depth 4 to 35 feet. Los Angeles: Long Beach Harbor: BS.

FAMILY SCIANIDAE - Croakers* or Drums

Black croaker. . . . .*Cheilotrema saturnam* (Girard)

Magdalena Bay, Baja California to Point Conception. Surface to 150 feet. Los Angeles-Long Beach Harbor: BS, DV1, S1, S3, T11, (only one fish taken in 46 trawls).

White seabass. . . . .*Cynoscion nobilis* (Ayres)
Magdalena Bay, Baja California to Juneau, Alaska. Surface to 400 feet. Los Angeles-Long Beach Harbor: BS, S3, S4.

White croaker. . . . . *Genyonemus lineatus* (Ayres)
Magdalena Bay, Baja California to Vancouver Island, B.C. Surface to 330 feet. Los Angeles-Long Beach Harbor: BS, GN3, HLA, HLC, HLD, HLE, S1, S2 (Fish Harbor, Terminal Island), S3, S4, T1-T17, U&G. Common.

California corbina . . . .*Menticirrhus undulatus* (Girard)
Gulf of California to Point Conception. Surface to 45 feet. Los Angeles-Long Beach Harbor: BS, HLA, S3, S4.

Spotfin croaker. . . . .*Roncador sternsii* (Steindachner)
Mazatlan, Mexico, to Point Conception. Surface to 50 feet. Los Angeles-Long Beach Harbor: BS, DV1, S3, S4.

Queenfish. . . . .*Seriphus politus* Ayres
West of Uncle Sam Bank, Baja California to Yaquina Bay, Oregon. Surface to 800 feet. Los Angeles-Long Beach Harbor: BS, GN3, HLA, HLD, S1, S3, S4, T3-T17, U&G, Common.

Yellowfin croaker . . . .*Umbrina roncador* Jordan & Gilbert
Gulf of California to Point Conception. Surface to 150 feet. Los Angeles-Long Beach Harbor: BS, S1.

FAMILY KYPHOSIDAE - Sea Chubs

Opaleye . . . .*Girella nigricans* (Ayres)
Cape San Lucas, Baja California to San Francisco. Intertidal to 95 feet. Los Angeles-Long Beach Harbor: DV1, GN1, S1, S3, U&G.

Halfmoon . . . . .*Medialuna californiensis* (Steindachner)
Gulf of California to Klamath River. Surface to 130 feet. Los Angeles-Long Beach Harbor: DV1, GN1, S1.

FAMILY EMBIOTOCIDAE -Surfperches

Barred surfperch . . . . . .*Amphistichus argenteus* Agassiz
Playa Maria Bay, Baja California to Bodega Bay. Surface to 130 feet. Los Angeles-Long Beach Harbor: BS, S3, S4.

Calico surfperch. . . . . . .*Amphistichus koelzi* (Hubbs)
Arroyo San Isidro, Baja California to Shi Shi Beach, Washington. Surface to 30 feet. Los Angeles-Long Beach Harbor: HLA.

Shiner surfperch . . . . . .*Cymatogaster aggregata* Gibbons
San Quintin Bay, Baja California to Port Wrangell, Alaska. Surface to 480 feet. Los Angeles-Long Beach Harbor: BS, DV1, GN1, GN3, HLA, HLB, HLC, HLD, HLE, S2 (sight record, Marina, Watchhorn Basin, San Pedro), Common.

Pile surfperch . . . .*Damalichthys vacca* (Girard)
Guadalupe Island to Port Wrangell, Alaska. Surface to 150 feet. Los Angeles-Long Beach Harbor: BS, DV1, GN1, HLA, HLE, S3, S4, T3, T4, T13-T14, Common.

Black surfperch . . . .*Embiotoca jacksoni* Agassiz
Point Abreojos, Baja California to Fort Bragg. Surface to 130 feet. Los Angeles-Long Beach Harbor: BS, DV1, GN1, HLA, HLB, HLC, HLD, HLE, S1, S3, S4, T3, T6, T7, T9-T14, T17, Common.

Walleye surfperch . . . . .*Hyperprosopon argenteum* Gibbons
Point San Rosarito, Baja California to Vancouver Island. Surface to 60 feet. Los Angeles-Long Beach Harbor: BS, HLA, HLD, HLE, S1, S3, S4, T1, T12, T13, T14, Common.

Dwarf surfperch. . . . . . *Micrometrus minimus* (Gibbons)
Cedros Island, Baja Californoa to Bodega Bay. Tide-pools to 30 feet. Los Angeles-Long Beach Harbor: BS.

White surfperch . . . .*Phanerodon furcatus* Girard
Point Cabras, Baja California to Vancouver, B.C. Surface to 140 feet. Los Angeles-Long Beach Harbor: BS,DV1, GN1, GN3, HLA, HLD, HLE, S4, T1-T17, U&G, Common.

Rubberlip surfperch . . . . . .*Rhacochilus toxotes* Agassiz
Thurloe Head, Baja California to Russian Gulch State Beach, Mendocino County, California. Surface to 150 feet. Los Angeles-Long Beach Harbor: BS, DV1, GN1, S3, S4, T2, T3, T6, T8-T13, Common.

Pink surfperch. . .*Zalembius rosaceus* (Jordan & Gilbert)
Gulf of California and San Cristobal Bay, Baja California to Drakes Bay. 30 to 300 feet. Los Angeles-Long Beach Harbor: S4.

Rainbow surfperch . . . .*Hypsurus caryi* (Agassiz)
Rio Santo Tomas, Baja California to Cape Mendocino. Surface to 130 feet. Los Angeles-Long Beach Harbor: DV1, GN1.

FAMILY POMACENTRIDAE - Damselfishes

Blacksmith. . . . .*Chromis punctipinnis* (Cooper)
Point San Pablo, Baja California to Monterey Bay. Surface to 150 feet. Los Angeles-Long Beach Harbor: DV1, GN1, S1, S3.

Garibaldi . . . .*Hypsypops rubicundus* (Girard)
Magdalena Bay, Baja California to Monterey Bay. Surface to 95 feet. Los Angeles-Long Beach Harbor: DV1, GN1, S1, S3.

FAMILY LABRIDAE - Wrasses

Rockwrasse . . . .*Halichoeres semicinctus* (Ayres)
Gulf of California to Point Conception. Surface to 78 feet. Los Angeles-Long Beach Harbor: S1.

Senorita . . . .*Oxyjulis californica* (Gunther)
Cedros Island, Baja California to Sausalito (Recent only to Santa Cruz). Surface to 180 feet. Los Angeles-Long Beach: DV1, S1.

California sheephead. . . .*Pimelometopon pulchrum* (Ayres)
Cape San Lucas, Baja California to Monterey. Surface to 180 feet. Los Angeles-Long Beach Harbor: DV1, GN1, S3.

FAMILY LUGILIDAE - Mullets

Striped mullet . . . .*Mugil cephalus* Linnaeus
Eastern Pacific, Galapagos Islands to Monterey. Surface to 400 feet. Los Angeles-Long Beach Harbor: BS, S3.

FAMILY SPHYRAENIDAE - Barracudas

California barracuda . . . . . .*Sphyraena argentea* Girard
Cape San Lucas, Baja California to Kodiak Island, Alaska. Surface to 60 feet. Los Angeles-Long Beach Harbor: BS, HLA, S1, S3.

FAMILY POLYNEMIDAE - Threadfins

Yellow bobo . . . .*Polydactylus opercularis* (Gill)
Callao, Peru, to Monterey. Shallow inshore areas. Los Angeles-Long Beach Harbor: Not taken in this study (see Miller & Lea, 1972, pg. 168).

FAMILIY CLINIDAE - Clinids

Spotted kelpfish . . . .*Gibbonsia elegans* (Cooper)
Magdalena Bay, Baja California to Point Piedras Blancas. Surface to 185 feet. Los Angeles-Long Beach Harbor: DV1.

Giant kelpfish . . . .*Heterostichus rostratus* Girard
Cape San Lucas, Baja California to British Columbia. Surface to 132 feet. Los Angeles-Long Beach Harbor: BS, HLC, DV1.

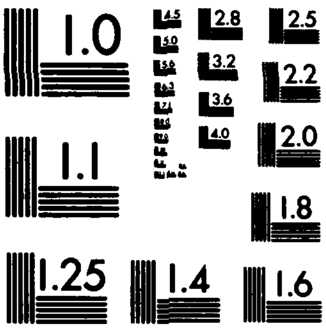
Sarcastic fringehead. . . . . .*Neoclinus blanchardi* Girard
Cedros Island, Baja California to San Francisco. 10 to 200 feet. Los Angeles-Long Beach Harbor: S4.

Yellowfin fringehead . . . . . .*Neoclinus stephensae* Hubbs
Point San Hipolito to Monterey 10 to 90 feet. Los Angeles-Long Beach Harbor: DV1 (sight record only).

Onespot fringehead . . . .*Neoclinus uninotatus* Hubbs
San Diego Bay to Bodego Bay. 10 to 90 feet. Los Angeles-Long Beach Harbor: BS, T10.

AD-A136 653 ENVIRONMENTAL INVESTIGATIONS AND ANALYSES FOR LOS ANGELES-LONG BEACH HARB..(U) UNIVERSITY OF SOUTHERN CALIFORNIA LOS ANGELES ALLAN HANCOCK F.. DEC 76 4/8

UNCLASSIFIED DACW09-73-C-0112 F/G 8/10 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

FAMILY BLENNIIDAE - Combtooth blennies

Rockpool blenny . . . . . . *Hypsoblennius gilberti* (Jordan)
Magdalena Bay, Baja California to Monterey. Intertidal to 80 feet. Los Angeles-Long Beach Harbor: HLA

Mussell blenny . . . *Hypsoblennius jenkinsi* Jordan & Evermann
Puerta Marquis, Mexico, to Coal Oil Point. Depth Intertidal to 70 feet. Los Angeles-Long Beach Harbor: BS.

FAMILY GOBIIDAE - Gobies

Longjaw mudsucker . . . . *Gillichthys mirabilis* Cooper
Gulf of California to Tomales Bay. Shallows of bays, mudflats. Los Angeles-Long Beach Harbor: S3.

Bay goby . . . . *Lepidogobius lepidus* (Girard)
Cedros Island, Baja California to Vancouver Island, B.C. Shallow bays and to 200 feet. Los Angeles-Long Beach Harbor: DV1, GN1, S4, T3-T11, T13, T14, T16, T17, Common.

Blackeye goby . . . . *Coryphopterus nicholsii* (Bean)
South of Point Rompiente, Baja California to Skidegate Channel, Queen Charlotts Is., B.C. 5 to 80 feet. Los Angeles-Long Beach Harbor: DV1, T4-T8, T11, T14, Common.

Arrow goby . . . . *Clevelandia ios* (Jordan & Gilbert)
Gulf of California to Vancouver Island, B.C. Shallow areas of bays. Los Angeles-Long Beach Harbor: Dip-netted in Fish Harbor: S2.

Chameleon goby . . . . . *Tridentiger trigonocephalus* (Gill)
Los Angeles Harbor and in San Francisco Bay. Shallow bay areas. Los Angeles-Long Beach Harbor: Not taken in this study (see Miller and Lea, 1972, pg. 186).

FAMILY SCOMBRIDAE - Mackerels & Tunas

Slender tuna . . . . *Allothunnis fallai* Serventy
Warm seas, mostly in southern hemisphere; north to Los Angeles Harbor. Depth: Inshore pelagic. Los Angeles-Long Beach Harbor: Not taken in this study (see Miller and Lea, 1972, pg. 194).

Wavyback skipjack* . . . . *Euthynnus affinis* (Cantor)
Indo-Pacific, north to Los Angeles Harbor on our coast. Epipelagic. Los Angeles-Long Beach Harbor: Not taken in this study (see Miller & Lea, 1972, pg. 192).

Pacific bonito . . . . *Sarda chiliensis* (Cuvier)
Chile to Gulf of Alaska. Epipelagic. Los Angeles-Long Beach Harbor: HLA, HLC, S1, S3, Common.

Pacific (Chub) mackerel . . . . *Scomber japonicus* Houttuyn
Transpacific, in eastern Pacific, Chile to Gulf of Alaska. Surface to 150 feet. Los Angeles-Long Beach Harbor: S1.

Monterey spanish mackerel . . . . *Scomberomerus concolor* (Lockington)
Gulf of California to Soquel. Nearshore pelagic fish. Los Angeles-Long Beach Harbor: BS.

FAMILY STROMATEIDAE - Butterfish

Pacific butterfish . . . . . *Peprilus simillimus* (Ayres)
Magdalena Bay, Baja California to Freser River, B.C. 30 to 300 feet. Los Angeles-Long Beach Harbor: BS, HLA, HLD, S1, S5, T12, T14, Common.

FAMILY SCORPAENIDAE - Rockfishes

Spotted scorpionfish . . . . *Scorpaena guttata* Girard
Uncle Sam Bank, Baja California to Santa Cruz. Shallow to 600 feet. Los Angeles-Long Beach Harbor: S1, S3, S4, T3, T9, Common.

Brown rockfish . . . . *Sebastes auriculatus* Girard
Hipolito Bay, Baja California to South East Alaska. Shallow to 180 feet. Los Angeles-Long Beach Harbor: T13 (only one fish taken in 46 trawls).

Calico rockfish . . . *Sebastes dallii* (Eigenmann & Beeson)
Sebastian Viscaino Bay, Baja California to San Francisco. 60 to 830 feet. Los Angeles-Long Beach Harbor: S4.

Chilipepper . . . . *Sebastes goodei* (Eigenmann & Eigenmann)
Magdalena Bay, Baja California to Vancouver Island. Surface to 660 feet. Los Angeles-Long Beach Harbor: T3, T8.

Vermilion rockfish . . *Sebastes miniatus* (Jordan & Gilbert)
San Benito Islands, Baja California to Vancouver Island, British Columbia. Shallow to 660 feet. Los Angeles-Long Beach Harbor: T3-T9, T16.

Blue rockfish . . . . *Sebastes mystinus* (Jordan & Gilbert)
Point Santo Tomas, Baja California to Bering Sea. Surface to 300 feet. Los Angeles-Long Beach Harbor: DV1 (sighted only, not taken in 46 trawls), S1.

Boccacio . . . . *Sebastes paucispinis* (Ayres)
Point Blanca, Baja California to Kodiak Island, Alaska. Surface to 1050 feet. Los Angeles-Long Beach Harbor: T3, T5-T8, T11, T12, Common.

Grass rockfish . *Sebastes rastrelliger* (Jordan & Gilbert)
Playa Maria Bay, Baja California to Yaquina Bay, Oregon. Intertidal to 150 feet. Los Angeles-Long Beach Harbor: DV1, HLC, S1.

Flag rockfish . . . *Sebastes rubrivinctus* (Jordan & Gilbert)
Cape colnett, Baja California to Aleutian Islands. 100 to 600 feet. Los Angeles-Long Beach Harbor: T8 (only one fish taken in 46 trawls).

Striptail rockfish . . . . . *Sebastes saxicola* (Gilbert)
Sebastian Viscaino Bay, Baja California to South East Alaska. 192 to 1320 feet. Los Angeles-Long Beach Harbor: T3, T5, T6, T7, T9, T12, Common.

Olive rockfish *Sebastes serranoides* (Eigenmann & Eigenmann)
San Benito Island, Baja California to Redding Rock, Del Norte County. Surface to 480 feet. Los Angeles-Long Beach Harbor: DV1, GN1, T3-T9, T11, T13, T16, Common.

FAMILY HEXAGRAMMIDAE - Greenlings

Kelp greenling . . . . . *Hexagrammos decagrammus* (Pallas)
La Jolla to Aleutian Islands, Alaska. Intertidal to 150 feet. Los Angeles-Long Beach Harbor: DV1,GN1.

Lingcod . . . . *Ophiodon elongatus* Girard
Point San Carlos, Baja California to Kodiak Island, Alaska. Surface to 1400 feet. Los Angeles-Long Beach Harbor: HLA.

FAMILY ZANIOLEPIDIDAE - Combfishes

Longspine combfish . . . . . *Zaniolepis latipinnis* Girard
San Cristobal Bay, Baja California to Vancouver Island, B.C. 120 to 372 feet. Los Angeles-Long Beach Harbor: S4.

FAMILY COTTIDAE - Sculpins

Bonyhead sculpin . . . . . . *Artedius notospilotus* Girard
Point San Telmo, Baja California to Puget Sound. Intertidal to 150 feetl Los Angeles-Long Beach Harbor: BS, S4, T8.

Roughback sculpin. *Chitonotus pugetensis* (Steindachner)
Santa Maria Bay, Baja California. Intertidal to 465 feet. Los Angeles-Long Beach Harbor: S4, U&G.

Wooly sculpin. . . . .*Clinocottus analis* (Girard)
Ascuncion Point, Baja California to Cape Mendocino. Intertidal to 60 feet. Los Angeles-Long Beach Harbor: DV1, GN1, S1, U&G.

Pacific staghorn sculpin. . . .*Leptocottus armatus* Girard
San Quintin Bay, Baja California to Chignik, Alaska. Intertidal to 300 feet. Los Angeles-Long Beach Harbor: BS, HLA, S1, S3, T11, T12, T13, T14, Common.

Cabezon . . . .*Scorpaenichthys marmoratus* (Ayres)
Point Abreojos, Baja California to Sitka, Alaska. Intertidal to 256 feet. Los Angeles-Long Beach Harbor: DV1, GN1, S1, S3.

FAMILY AGONIDAE - Poachers

Pygmy poacher . . . . . .*Odontopyxis trispinosa* Lockington
Cedros Island, Baja California to South East Alaska. 30 to 1208 feet. Los Angeles-Long Beach Harbor: T3, T6-T9, T16, U&G.

Order Pleuronectiformes (Heterosomata)

FAMILY BOTHIDAE - Left-eye flounders

Pacific sanddab . . . . . .*Citharichthys sordidus* (Girard)
Cape San Lucas, Baja California to Bering Sea. 30 to 1800 feet. Los angeles-Long Beach Harbor: T13 (only one fish taken in 46 bottom trawls), Rare, U&G.

Speckled sanddab . .*Citharichthys stigmaeus* Jordan & Gilbert
Magdalena Bay, Baja California to Montaque Island, Alaska. 10 to 1200 feet (?). Los Angeles-Long Beach Harbor: BS, S3, T2-T14, T16, Common, U&G.

Longfin sanddab . . . . .*Citharichthys xanthostigma* Gilbert
Costa Rica to Monterey Bay. Depth 8 to 44 feet. Los Angeles-Long Beach Harbor: BS, U&G.

Rex sole . . . .*Glyptocephalus zachirus* Lockington
San Diego trough to Bering Sea. Depth 60 to 2100 feet. Los Angeles-Long Beach Harbor: BS.

Bigmouth sole . .*Hippoglossina stomata* (Eigenmann & Eigenmann)
Gulf of California to Monterey Bay. 100 to 450 feet. Los Angeles-Long Beach Harbor: S4, T6, T9, T10.

California halibut . . . .*Paralichthys californicus* (Ayres)
Magdalena Bay, Baja California to Quillayute River, B.C. Surface to 300 feet. Los Angeles-Long Beach Harbor: BS, HLA, HLE, S1, S3, T3, T4, T6, T7, T8, T10-T14, G16 U&G, Common.

Fantail sole . . . . .*Xystreurys liolepis* Jordan & Gilbert
Gulf of California to Monterey Bay. 15 to 260 feet. Los Angeles-Long Beach Harbor: BS, S4, T9, T10, T11, T13, T14, U&G.

FAMILY PLEURONECTIDAE - Right-eye flounders

Petrale sole . . . .*Eopsetta jordani* (Lockington)
Los Coronodos Islands, Baja California to Gulf of Alaska. 60 to 1500 feet. Los Angeles-Long Beach Harbor. S4.

Diamond turbot . . . .*Hypsopsetta guttulata* (Girard)
Magdalena Bay, Baja California to Cape Mendocino. 5 to 150 feet. Los Angeles-Long Beach Harbor: BS, S3, S4, T9, T10, T14, U&G.

English sole . . . .*Parophyrys vetulus* Girard
San Cristobal Bay, Baja California to North West Alaska. 60 to 1000 feet. Los Angeles-Long Beach Harbor: BS, S3, S4, T3, T4, T6, T9-T11, T14, U&G.

C-O turbot. . . . .*Pleuronichthys coenosus* Girard
Cape Colnett, Baja California to South East Alaska. Shallow to 210 feet. Los Angeles-Long Beach Harbor: BS, Rare.

Curlfin turbot . . .*Pleuronichthys decurrens* Jordan & Gilbert
San Quintin Bay, Baja California to North West Alaska. 60 to 1140 feet. Los Angeles-Long Beach Harbor: BS, S3, S4, T6-T11, T13, T14, Common.

Spotted turbot. . . .*Pleuronichthys ritteri* Starks & Morris
Magdalena Bay, Baja California to Point Conception. 4 to 150 feet. Los Angeles-Long Beach Harbor: BS, S4,G9 (only one fish taken in 46 bottom trawls), U&G.

Hornyhead turbot. .*Pleuronichthys verticalis* Jordan & Gilbert
Madgalena Bay, Baja California to Point Reys. 30 to 612 feet. Los Angeles-Long Beach Harbor: BS, S1, S3, S4, T2-T14, U&G.

FAMILY CYNOGLOSSIDAE - Tonguefishes

California tonguefish. .*Symphurus atricauda* (Jordan & Gilbert)
Cape San Lucas, Baja California to Big Lagoon, Humboldt County. 5 to 276 feet. Los Angeles-Long Beach Harbor: BS, S3, S4, T2-T14, T16, T17, Common, U&G.

APPENDIX 2. Fish species from Ulrey and Greeley (1928), prior to completion of the middle and east breakwaters and the Long Beach land fills. These species are not included in check list because they have not been taken in recent collections from the harbor area. Scientific names in parenthesis are current taxonomy. Common names in parenthesis are current usage.

Brown ragfish, *Acrotus willoughbyi*
American shad, *Alosa sapidissima* (Wilson)
Coal fish (sablefish), *Anoplopoma fimbria* (Pallas)
California clingfish, *Arbaciosa (Gobiesox) rhessodon* (Smith)[1]
Reef finspot, *Auchenopterus (Paraclinus) intergripinnis* (Smith)[1]
Frigate mackerel, *Auxis thazard* (Lacepede)
Fanfish, *Brama raii (Pteraclis aesticola* Jordan & Snyder)
Deepwater blenny, *Cryptotrema corallinum* Gilbert
Shortfin corvina, *Cynoscion parvipinnis* Ayres (Not seen since 1930's along coastline, Miller and Lea, 1972)
Gilbert (bearded) clingfish, *Gobiesox papillifer* Gilbert
Bay blenny, *Hypsoblennius gentilis* (Girard)[1]
Yellowchin sculpin, *Icelinus quadriseriatus* (Lockington)
Gizzard shad, *Lophotes cepedianus* (Le Sueur)
Slender sole, *Lyopsetta exilis* (Jordan and Gilbert)
Slimy snailfish, *Neoliparus mucusus (Liparis mucosus* Ayres)
(Pacific) snake eel, *Ophichthys (Ophichthus) triserialis* (Kaup)
Sharpnose surfperch, *Phanerodon atripes* (Jordan & Gilbert)
Ragfish, *Schedophilus heathi (Icosteus aenigmaticus* Lockington)
Greenspotted rockfish, *Sebastodes (Sebastes) chlorostictus* (Jordan & Gilbert)
Barred pipefish, *Syngnathus auliscus* (Swain)[2]
Bay pipefish, *Syngnathus leptorhynchus (griseolineatus* Ayres)[2]
Pithead sculpin, *Tarandichthys (Icelinus) cavifrons* Gilbert

---

[1]Very probably present in Los Angeles-Long Beach Harbor but not seen or taken due to sampling methods in the present study.

[2]May be *Syngnathus sp.* in checklist.

Chapter 8

MARINE-ASSOCIATED AVIFAUNA

OF LOS ANGELES-LONG BEACH HARBORS

MARINE-ASSOCIATED AVIFAUNA OF LOS ANGELES-LONG BEACH HARBORS

INTRODUCTION

The avifauna survey was undertaken by Harbors Environmental Projects to determine the numbers, seasonality, and also the distribution of birds within the Los Angeles Harbor Basin. Observations were made from February 12, 1973 to November 24, 1974, a period of 22 months. For the purposes of this report, only data from August 10, 1973 to September 29, 1974 have been analyzed in detail, taking this period to be representative of the activity found throughout the time of the survey. During this 14-month period, the harbor was surveyed 43 times.

SCOPE

The entire Los Angeles Harbor and certain portions of the Long Beach Harbor, including the Pier J basin, the Long Beach Channel, the East Basin of the Long Beach Harbor, and the Cerritos Channel and its associated slips were surveyed. The U.S. Navy areas were not surveyed, with the exceptions of the seaplane basin and the seaward side of the Navy Mole.

All species of birds observed feeding in or using the harbor were included, and while this list of species is composed mainly of coastal and marine birds, a few non-marine species that make significant use of the harbor are also included.

METHODS

The methods devised for data acquisition were quite simple and relied entirely upon on-site identification and enumeration of birds present. An 18-foot Boston Whaler equipped with a 50 H.P. outboard motor was operated by Harbor Project personnel, at the direction of the investigators. At various locations in the harbor, the birds present were counted and listed by species, age where possible, and behavior. Observations were recorded by hand for the first six months and after that time were recorded on a tape recorder; the tapes were later transcribed for computer entry.

The area of survey was divided into 51 stations, numbered x50 through x100. Stations x98 through x100 were excluded from the computer analysis because they were open water stations infrequently censused either because they seldom contained many birds, or were not sufficiently different from the surrounding stations. These three stations are of limited significance, in that they are not closely associated with land features of the harbor, which makes them fairly isolated,

and are used primarily by birds in transit. The station division segments of the harbor are shown on Figure 8.1 and a description of each of the stations is included in a later section of the report.

The harbor was surveyed approximately weekly, usually on the weekends. The survey was started between 8 a.m. and 9 a.m. each day and as many stations as possible were surveyed on each day. In many cases, due to the amount of time needed to cover the stations, the inner harbor was surveyed one week and the outer harbor the following week.

Birds observed were classified by species along accepted lines of bird field identification. Birds were age-classed into three categories:

ADULT - birds recognized as adults by accepted field marks;
IMMATURE - birds recognized as immature or non-adult by accepted fieldmarks;
UNKNOWN - species in which age distinction is impossible in the field, and for those species in which adults and immatures cannot be separated in the field, at certain times of the year.

Birds observed were also segregated into four behavior groups:

FEEDING - birds actively involved in the search for or acquisition of food;
FLYING - birds in transit, moving from one area to another;
RESTING - birds at rest or non-active on perches or in the water;
UNSPECIFIED - birds whose behavior cannot be classified into one of the other categories, either due to the habits of the species as a group, or to the behavior of individuals within a species.

Observations were made with binoculars at ranges of 5-50 meters, as close as practical to the birds. All birds were counted, even when in large groups, and estimations of numbers were made only for groups that could not be counted, such as large flying groups. Observations were tape-recorded on-site, and the tapes later transcribed. Although the survey was conducted for 22 months, the analysis is limited to a 14-month period. This was done to obtain data from the period when the harbor was surveyed consistently the same day of the week, after methods were well-established, and to obtain data from a period that would permit computer analysis due to the large quantity of data and consistency of methods.

The survey team usually consisted of three persons, a boat operator and two observers, Tom Webber and Elizabeth Copper, with Robert Copper assisting occasionally. The observers identified and counted birds, each taking separate species when the birds were found in large, mixed groups. Unusual species were confirmed by both observers. The observers alternated on using the tape recorder for the data for

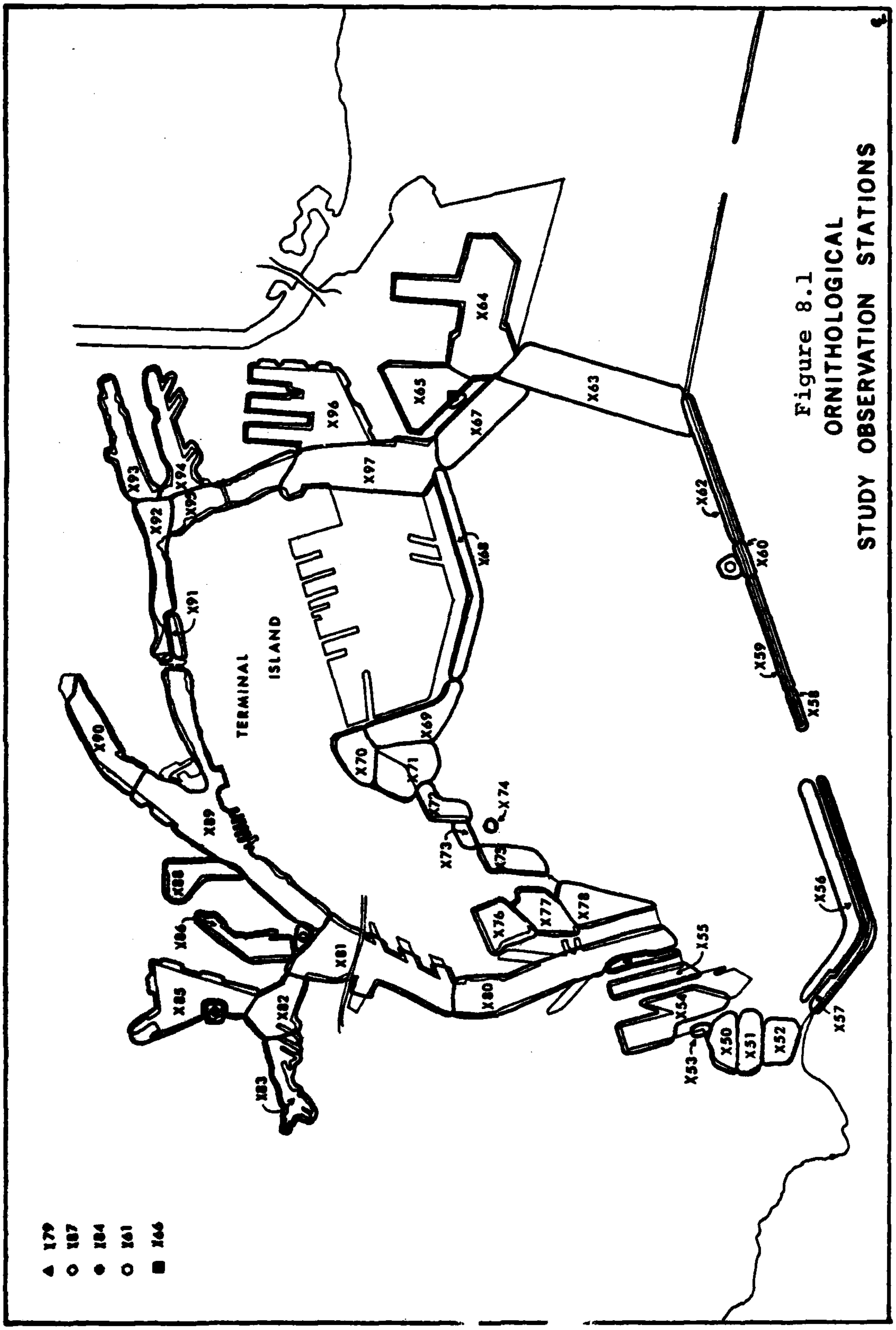


Figure 8.1
ORNITHOLOGICAL
STUDY OBSERVATION STATIONS

the observation; because the methods are quite simple and straightforward, they afford information that is direct and true, as on-site investigation tends to be. While many minor procedural points were modified in the early months of the survey, the basic method seems to be adequate to this type of task.

POTENTIAL ERROR-INDUCING FACTORS

A number of potential error factors should be considered in determining the accuracy of the study. These are listed below with a brief discussion.

1) Observer expertise. This factor is hopefully of little significance because of the experience of the observers; however, other experienced persons were occasionally invited to audit the identifications so that corrections and verifications could be made.

2) Counting error. This factor also appears to be of little significance. The two observers and selected third parties verified counting accuracy by all counting the same groups on occasion, and deviations in counting groups of over 100 birds seldom exceeded $\pm$ 1%.

3) Sampling bias, physical. A bias is present in that the survey deals with birds associated with land forms in the harbor, and little attention was paid to birds in the main open water of the outer harbor. The outer harbor was surveyed to the extent necessary to determine that the open water area is used mainly by birds in transit.

4) Sampling bias, temporal. Two temporal biases exist. First, the survey was run consistently on weekends when recreational use of the harbor is greatest. It was determined, however, from comparison of data taken early in the survey on weekdays, that the variation in avian distribution is very small, due to the limited recreation facilities in the harbor and the fact they receive some use through the entire week.

The second temporal bias is that introduced by the usual inability to survey the entire harbor in one day. In most of the survey period, the inner harbor was surveyed one week and the outer harbor the next. While this introduces a bias, it was necessary to survey the harbor this way.

5) Weather. During rough and stormy weather surveying the harbor was very difficult, and the data gathered tended to be spotty and incomplete. As a result, most bad weather dates were excluded from the computer analysis, including two during the 14-month period. On these days, observations were made for only one or two hours at a few stations.

6) Ship locations. The presence or absence of ships

at the docks definitely influenced the presence or absence of birds at those stations. No attempt was made to coordinate observations with dock use, which does influence distribution in the harbor; however, it probably does not influence the total number of birds in the harbor and may not always influence the totals at a particular station.

7) Data handling. Errors are possible in all stages of data handling from tape transcription to computer entry. This was minimized by having one person transcribe tapes, spot checking transcription accuracy, and usual computer quality control methods.

RESULTS

The systematic results for the two-year study are presented according to family, with a brief discussion of the species.

GAVIIDAE (Loons)

Gavia immer (Common Loon). Arrived at the harbor in late June in both years accompanied by young, and stayed until the beginning of September; this species disappeared from the harbor until December, and individuals were seen until mid-March. The number of this species occurring in the harbor is relatively small and fairly constant with a slight increase in the numbers seen in the summer. Normally expected to be a winter resident, the birds seen in the summer are apparently birds which nested early and migrated south quite early. It is almost always found in open water in the outer harbor, particularly station 56.

Gavia arctica (Arctic Loon). Seen sporadically from August through April, always in very small numbers. Several individuals have been sighted in June and July; these may be birds which have chosen to summer over or they may be early returnees. This species is seen in the same areas of the harbor as the other members of this family.

Gavia stellata (Red-Throated Loon). In the first year of the survey this was by far the most common member of the family in the study area, but in the second year it was replaced by the Common Loon. Like the other members of its family, it is seen sporadically throughout the year with slightly more birds present during the summer. This species was seen during the first year mainly at Cabrillo Beach and in the seaplane basin; however, in the second year was found more often in station 56.

PODICIPEDIDAE (Grebes)

Podiceps auritus (Horned Grebe). Seen in the winter months infrequently up until March. This species is found in almost all sheltered parts of the harbor.

Podiceps nigricollis (Eared Grebe). September through May with great regularity. Its peak populations occur from November to January, and is found throughout the harbor. There is a tendency for these birds to flock just prior to spring migration.

Aechmorphorus occidentalis (Western Grebe). Occurs from August through May with a peak occurring in December. It is generally found in calm water in sheltered areas, particularly in stations 56 and 64. In the first year of observation, it occurred in flocks that at times numbered over 300. In the second winter, however, the numbers were drastically reduced with flocks seldom numbering more than 20. This is of particular importance, for throughout its range this species is decreasing in number.

Podilymbus podiceps (Pied-billed Grebe). Rare in the harbor, with only three or four sightings of single individuals each winter. This species is normally more common in salt water areas than these observations would indicate.

PROCELLARIIDAE (Shearwaters)

Puffinus griseus (Sooty Shearwater). A strictly pelagic bird, one of this species was seen feeding at station 55 on December 1, 1973. This particular day was extremely stormy, which would account for this bird's presence.

PELECANIDAE (Pelicans)

Pelecanus occidentalis (Brown Pelican). Seen throughout the period only on the middle breakwater; however, during its peak periods, primarily in September, it may be seen at most stations in the harbor.

PHALACROCORACIDAE (Cormorants)

Phalacrocorax auritus (Double-crested Cormorant). Major concentrations along reinforced shoreline from Fish Harbor to the seaplane basin. As many as 130 of this species were found roosting in the seaplane basin on some days in mid-winter. In the outer harbor area on February 18, 1974, 114 were seen, whereas only a total of 50 were seen on May 25, the majority of which were in the seaplane basin. Up to the middle of July there has remained a stable group of 20 to 25 in the seaplane basin. In 1974 there was a marked decrease in the numbers of this and all of the cormorant species.

Phalacrocorax penicillatus (Brandt's Cormorant). Far fewer in number than the Double-crested. Brandt's are most commonly seen in smaller groups along the outer breakwater and in the Navy seaplane anchorage. A few individuals are seen sporadically throughout the harbor. Most numerous in the harbor from February to April, this species greatly decreased in the second year and was seen only in small numbers throughout the winter months.

Phalacrocorax pelagicus (Pelagic Cormorant). Approximately equal to or slightly greater in number than the Brandt's. Most commonly seen in the winter months up to April along the outer breakwater and along the shore from Pier J to the seaplane basin. During the period of observation the Pelagic Cormorant has never been seen in the inner harbor or at Cabrillo Beach. Eighteen were seen near the seaplane anchorage on February 23. From April to mid-July of 1973, there was only one sighting; in the second year there were a few sightings, only of single individuals, occurring sporadically from November to April.

ARDEIDAE (Herons)

Ardea herodias (Great Blue Heron). During February, 1973, a group of nine was observed on three occasions in various parts of the eastern portion of the outer harbor, roosting on the outer breakwater, the seaplane basin breakwater, and flying over Pier J. During the 14-month analysis periods, birds were seen regularly from August, 1973 to March, in fairly large numbers.

Butorides virescens (Green Heron). Seen sporadically at widely separated areas of the inner harbor. Habit is to perch near the water on docks, gravel banks, and sandy beaches. Seen only February to March.

Egretta thula (Snowy Egret). One seen in February on the rocks in the basin of Pier J. Two were seen foraging in shallow water at the entrance to Dominguez Slough in late May, plus two additional sightings of single individuals in September and December.

Nycticorax nycticorax (Black-crowned Night Heron). One individual (immature) seen on pilings in Fish Harbor in late April, and another individual seen on pilings in the main channel near the entrance to West Basin in May. This nocturnal species probably occurs more commonly than noted. Single individuals were also seen in August and September.

ANATIDAE (Ducks and Geese)

Branta nigricans (Black Brant). A flock of 17 flew over the outer breakwater, heading north toward the inner harbor on March 5. One was seen at a temporary rain-water pool near the tuna canneries, and a group which varied between five and six was seen at Cabrillo Beach from early May to the middle of May. The occurrence of this species is somewhat unusual in the harbor area, as they have very specific feeding requirements (*Phyllospadix* or *Zostera* - eel grass), which are not found in the harbor. In addition to previous sightings a single bird was seen at station 73 in November.

Anas acuta (Pintail). A flock of six sitting on the water near station 71, though not close to the outfalls on February 19. Two seen flying over the breakwater on April 13.

Anas cyanoptera (Cinnamon Teal). A flock of ten on the water in Pier J on February 16, 1973, and a flock of 24 with the above-mentioned Pintails on February 19. There were additional sightings in December, January and March, with 77 seen on January 19, 1974 at station 73.

Aythya affinis (Lesser Scaup). One seen on February 9, 1973 in the western arm of West Basin, and a flock of eight on the water near station 75 though not near the outfalls on February 16, 1973. From December, 1973 through March, 1974 a flock was seen sporadically in station 70, peaking at 29 birds seen January 5, 1974.

Melanitta perspicillata (Surf Scoter). Abundant from the winter months up to April at Cabrillo Beach, in the seaplane basin, Pier J, at the entrance to Fish Harbor and in the open water of the outer harbor near the seaplane anchorage, as well as off the Navy Mole, with small scattered groups in the main channels. As an illustration, on February 15, 1973, there were 265 Surf Scoters in Pier J, 57 in and near Fish Harbor, and 53 at Cabrillo Beach. Virtually all were gone by April 16.

Melanitta nigra (Common Scoter). One seen on water in Pier J with large flock of Surf Scoters on February 26, 1973, and again on the fifth and sixteenth of March, 1973. There was also one observed between stations 64 and 65 on March 16, 1973. There were single sightings in November and December of 1973, and January and April of 1974, along the Navy mole.

Melanitta deglandi (White-winged Scoter). One immature male seen with Surf Scoters in the seaplane anchorage on June 29. There were eight scattered sightings of birds from August, 1973 to April, 1974. In January two birds were seen in station 68.

Oxyura jamaicensis (Ruddy Duck). One seen in the large arm of the West Basin on February 9, and one in the seaplane basin on February 16, 1973. Three additional sightings in September, 1973 and March and May of 1974.

Mergus merganser (Common Merganser). Two at station 59 on June 30, 1974. These birds were resting on the breakwater.

Mergus serrator (Red-breasted Merganser). Most often found near Cabrillo Beach. An average of about ten per day were on the water in that area from February to April. This species is also seen regularly along the stretch of the outer breakwater nearest Cabrillo Beach in groups of three or four.

Never seen in inner harbor. Three remained near Cabrillo Beach until May 25, 1973. This species was seen in small numbers from November, 1973 to April, 1974, primarily near the middle breakwater.

PANDIONIDAE (Ospreys)

Pandion haliaetus (Osprey). One seen feeding at station 52 on April 20, 1974, and one seen in the same place on August 10, 1973.

FALCONIDAE (Falcons)

Falco sparverius(American Kestrel). One seen at station 94 on March 22, 1974. Most likely a migratory bird.

RALLIDAE (Rails)

Fulica americana (American Coot). A familiar sight in most areas, however in the harbor it is an unusual bird with only five sightings: two in September of 1973, two in September of 1974, and one in December of 1973. They were found in various parts of the harbor and most, if not all, were in migration.

HAEMATOPODIDAE (Oystercatchers)

Haematopus bachmani (Black Oystercatcher). Two seen on the outer breakwater in the first week of May, 1973. Three additional sightings of single birds in late May and early June, 1973.

CHARADRIIDAE (Plovers, Turnstones and Surfbirds)

Charadrius vociferus (Killdeer). One or two can always be found in areas above the beach at Cabrillo Beach. Also seen infrequently at the extreme upper end of the west arm of the West Basin (LA) and in the fields between the tuna canneries and the Navy seaplane anchorage. This species undoubtedly nests in the Cabrillo Beach area and in the area near the canneries.

Charadrius alexandrinus (Snowy Plover). Seen on only two occasions. Four were seen at station 50 on August 17, 1973 and five were seen in the same place on November 3, 1973. This species is notably absent here presumably because the proper habitat is not available. Also, this species may not be as adaptable to human presence as other small sandpipers (i.e.Sanderlings).

Charadrius hiaticula (Semipalmated Plover). Seen on two dates; on December 15, 1973, three were observed at station 91 and on August 15, 1973, one was seen at station 50.

Pluvialis squatarola (Black-bellied Plover). About four seen

per day of observation, from February to April, 1973. Seen singly or in groups of two or three on the outer breakwater, at Cabrillo Beach and along shore from station 75 to the seaplane anchorage. Exceptionally large numbers were noted on the outer breakwater in March of 1973 (40 on March 5, 13 on March 16, and 23 on March 17). This species was noted from August on, throughout 1974 with the peak numbers being reached in mid-January.

Aphriza virgata (Surfbird). During February to March, 1973, seen individually or in pairs on the outer breakwater and rocks near the seaplane anchorage. Migratory concentrations occurred on March 30 with 24 birds seen at station 71; 34 birds were seen on the second and sixth of April at Cabrillo Beach. The peak was reached the ninth of April with 83 birds observed, the bulk of which were feeding along the breakwater which borders the Navy base. Seen from August 1973 to May 1974 with the migration peak falling on April 20, 1974 and totalling 89 birds, 68 of which were at station 52.

Arenaria interpres (Ruddy Turnstone). Approximately three observed per day of observation during February and March of 1973 on the outer breakwater, and on the rocks near the seaplane basin. Sixteen were seen at Cabrillo Beach on March 30, and 10 were seen in the same place on April 6. Some birds summered over and numbers were seen from August to April with the peaks coming in August and March.

Arenaria melanocephala (Black Turnstone). Found in the same areas as the Ruddy Turnstone. The migratory influx began earlier than that of the Ruddy Turnstone. Ten were seen on February 19, 21 on February 23, 18 on March 5, 19 on March 17, with the peak reached April 6, 1973, when 31 birds were observed, primarily along the breakwater. There are sightings for this species with good numbers occurring through the winter months. The migration peak in 1974 is reached on April 20.

SCOLOPACIDAE (Sandpipers)

Numenius phaeopus (Whimbrel). A lone Whimbrel stayed at Cabrillo Beach from February 23 to April 13, 1973. This bird was joined by two others in late April. On May 25, 1973 what were probably the same three individuals were seen flying over the open water of the outer harbor from the direction of Cabrillo Beach, and found standing on the outer breakwater. In 1974 there were only three sightings, two in January and one in March.

Actitis macularia (Spotted Sandpiper). Individual birds seen only between early August and mid-April, mostly on rocks and docks on the water's edge in the main channels and on the perimeters on the inner harbor.

Heteroscelus incanus (Wandering Tattler). Found primarily along the outer breakwater. Approximately one seen per day of observation, except during migratory peaks; 16 birds were seen on May 7, and nine birds were seen on May 14, 1973. Two birds were in Fish Harbor on July 20, 1973. This bird is primarily a winter resident and in 1974 had left the harbor by late April.

Catoptrophorus semipalmatus (Willet). Occupies primarily the rocky shoreline from Fish Harbor to station 71, and the outer breakwater, with individuals spread sparsely throughout the harbor. Greatest abundance occurred in late March and early April, along the shore from Fish Harbor to station 71, with 45 seen on March 25, 34 on March 30, 48 on April 9, 24 on April 13, and 86 on April 16, 1973. The numbers then sharply declined and by May 18 only two Willets were present in the harbor. Birds were seen from August 1973 to May 1974, with the greatest numbers coming in January and March.

Calidris minutilla (Least Sandpiper). This species has a curious distribution, unique among the harbor birds. From February 16 to March 30, 1973, these birds were seen almost solely at low tide on alga-covered blocks of broken concrete reinforcing the shoreline along the length of station 69 near the seaplane anchorage. Sample dates and numbers in this area: 3 on February 16, 11 on February 26, 18 on March 16, 20 on March 30, and 8 on April 16, 1973. The areas used by this species are consistent throughout the two-year period. The peaks occur in August and October of 1974.

Calidris alpina (Dunlin). Two were seen wading in the shallows of the fresh-water pond at station 73 on May 4, 1973. One was seen on the beach between the outfalls on May 7, 1973. Not found in the harbor until late April and early May, 1974, when it is found in small numbers at station 73.

Limnodromus scolopaceus (Long-billed Dowitcher). Flock of five on February 19, 1973, flying over the outer breakwater toward the inner harbor. Two were seen on April 9, 1973, on the beach between the outfalls. In 1974 this species was seen only twice, once on January 19, and once on March 30.

Calidris mauri (Western Sandpiper). Abundant for a short while at Cabrillo Beach, with 100 feeding there on April 3, 1973. Forty-three were seen on April 13, in mixed flocks with Sanderlings, Surfbirds, and Turnstones, 100 were seen on April 9, on the barge by the entrance to Fish Harbor, and on the same date, 76 were seen along the shore from Fish Harbor to station 71. By May 14, 1973, only an isolated individual remained. Occurred on scattered dates through the winter of 1974, and reached a peak on April 27 when there were 100 birds seen at station 52.

Limosa fedoa (Marbled Godwit). In 1973 the Marbled Godwit was found most reliably at the small beach at station 72 prior to completion of the fill operation there. This species was also seen at the small beach at station 75, and at Cabrillo Beach. During the winter months an average of about 4 Marbled Godwits were seen per day of observation in these locations. Seen again once in August, 1973, and then with some regularity from October to April, 1974, though always in small numbers.

Calidris alba (Sanderling). A group of about 250, seen every day of observation from February to April, 1973. Mainly observed along the rocks and beach from Fish Harbor to the seaplane basin. In early April, the distribution shifted to Cabrillo Beach where 93 were feeding on April 6, and 137 were there on April 13. On the same dates 50 were on the beach at station 75 on April 6, and 84 were distributed elsewhere throughout the outer harbor on April 13. There were only 36 by May 14, and these were gone from June to September. They stayed to early May, 1974, with the greatest peak on December 29, 1973, when there were a total of 543 Sanderlings seen, 500 of which were found at station 75.

Recurvirostra americana (American Avocet). Fifteen birds were seen feeding at the rain-formed fresh-water pond at station 73 on May 4, 1973. No others were observed during the entire two year survey period.

PHALAROPODIDAE (Phalaropes)

Steganopus tricolor (Wilson's Phalarope). One seen feeding in the pond at station 73 on May 4, 1973.

Lobipes lobatus (Northern Phalarope). Two were standing on the outer breakwater on February 19, 1973.

STERCORARIIDAE (Jaegers)

Stercorarius pomarinus (Pomarine Jaeger). One bird seen on September 8, 1974 at station 67, harassing gulls.

Stercorarius parasiticus (Parasitic Jaeger). On October 6, 1973, two were seen at station 63 feeding. On November 3, 1973, one was seen at station 71, and on August 25, 1974, two immature birds were seen feeding at station 56.

LARIDAE (Gulls and Terns)

Larus hyperboreus (Glaucous Gull). A single bird was seen feeding at station 75 on February 2 and 16, 1974.

Larus glaucescens (Glaucous-winged Gull). Found predominantly in the Dominguez Slough; 57 were seen there on February 16, 30 on February 19, 6 on March 16, and by April 6 only one was seen. Single birds were seen on most days of observation, until the end of May. They returned in late October, 1973, and were seen regularly from then until early June, 1974, with the peak numbers coming in mid-December. Individuals were seen in the main channels, Fish Harbor, Pier J, and on the outer breakwater throughout this period in 1973.

Larus occidentalis (Western Gull). This species is found everywhere in the harbor. This species occupies pilings, piers, docks, breakwaters, beaches, channels, and open water. Examples: 355 present in the harbor on March 17, 317 on April 2, 702 on May 18,1973. The numbers are spread rather evenly throughout the harbor. The second most numerous bird in the harbor after Heermann's Gull, it was seen on all 43 dates of the 14-month analysis period while the Heermann's Gull was missing on two of those dates. The birds were here in large numbers from August 1973 to late June, 1974, dropping off markedly during the month of July.

Larus thayeri (Thayer's Gull). One was identified on the pilings in the Dominguez Slough on February 26, 1973. This species is difficult to distinguish in the field and its presence remains questionable. It is probably present in small numbers through all but the summer months.

Larus argentatus (Herring Gull). Individuals and small groups found throughout the harbor. About five birds were seen per day of observation. In 1973 ten were seen on April 6, nine on April 13. By the sixteenth of April there was only one bird present. Seen from August 1973 to May 1974, with a remarkable peak for this species in November, 1973 when 36 birds were observed, 20 of which were roosting at station 90.

Larus californicus (California Gull). Very abundant in the winter months in the inner harbor, but unlike the Western Gull, this species seldom occurred on the outer breakwater. Found resting on pilings, piers, docks, beaches, roofs of buildings and on the water in the basins of the inner harbor. During the winter the Dominguez Slough is a major concentration point. On February 26, 1973, 600 California gulls were found on the water, pilings and docks of Dominguez Slough. On March 17, 1973 885 birds were present in the inner harbor area, 192 of which were in the Dominguez Slough. On March 16, a flock, roughly estimated at 1500 birds, virtually all of which were California gulls, circled high over West Basin (LA). April 16 there were approximately 1200 gulls of which only 23 were in the outer harbor breakwater area. By May 18 there were large concentrations in the Dominguez Slough area, flocks of over 200 were on the beach at Cabrillo. By mid-June, 1973, only one or two birds were found in the entire harbor and all

were gone in July. Maximum numbers occurred between late September, 1973 and the end of January, 1974, then tapered off slowly until late April when they fell abruptly.

Larus delawarensis (Ring-billed Gull). Like the California Gull this species avoids the outer breakwater, but is otherwise found throughout the harbor in the winter months. Peak days during the observation period were February 16 and 19, 1973, on which days 243 and 218 birds were present, respectively. Typically, Ring-billed Gulls in the harbor diminished gradually, until by the end of May only three or four birds were present.

Larus canus (Mew Gull). This species is found in small numbers near Fish Harbor, in the Dominguez Slough, in the main channels, and near the seaplane basin. From February to April 12, about three birds seen per day of observation. An exception is the flock of 35 seen on Cabrillo Beach on March 17. By April 16, there was only one immature bird on Cabrillo Beach. They returned in late October, 1973, but were not seen with any regularity until late December. Numbers reached their maximum in early February and fell off very abruptly thereafter, with all birds gone by the end of May, 1974.

Larus philadelphia (Bonaparte's Gull). From February to March this species seldom seen anywhere but the sewer outfall near station 73. An average of about 25 per day of observation were present in 1973. Bonaparte's Gulls became more numerous and widespread beginning in early April. On April 2, 131 were counted in the harbor. Most were in the sewer outfall (75 birds), and the rest were scattered over the outer harbor. 160 were roosting on Cabrillo Beach on April 13. The numbers gradually decreased, with only 91 birds present on May 14, and 55 birds on May 18. None were present after the end of May. Maximum numbers were reached in late December, 1973, and then fell off quickly except for a slight rise late in April, 1974.

Larus heermanni (Heermann's Gull). The most numerous gull in the harbor, it uses all areas of the harbor, especially the middle breakwater. A typical winter day of observation on March 17, 1973 yielded 342 Heermann's Gulls, with rather even numerical distribution throughout the harbor. By May 18 there were 108 birds, having gradually diminished, with most of the adult birds gone. Throughout the winter months, the immature birds greatly outnumbered the adults. By the end of June and the beginning of July, however, the number of Heermann's Gulls increased, with an unusually high proportion of adults.

Rissa tridactyla (Black-legged Kittiwake). In 1973 one was seen flying near the outer breakwater on February 16 and March 5. One was seen sitting on the outer breakwater at the end of April. The winter of 1973 was a fairly typical year for

the Kittiwake but 1974 was quite atypical. Large numbers of birds were seen, with the first arriving in late December, 1973, and the peak occurring in mid-March, 1974 when some 66 birds were present. They tapered off slowly with a few birds present on through the fall of 1974. With only one or two exceptions, the Kittiwakes were found in stations 60 and 61.

Sterna forsteri (Forster's Tern). Seen at one time or another at most stations in the harbor, this species was found primarily in the vicinity of Cabrillo Beach, flying over the main channel from the entrance to the Vincent Thomas Bridge, and flying near the outer breakwater. In 1973, they were present on March 5, and increased gradually until May 14 when 167 were present in the outer harbor, 69 of which were at the freshwater pond at station 73. The numbers then gradually declined, with 89 present by the end of May. After that, sightings were of individuals. Seen during every month.

Sterna hirundo (Common Tern). In 1973, one was observed at Cabrillo Beach on March 30. A banded individual was seen on two dates in the winter of 1974, in the seaplane basin.

Sterna albifrons (Least Tern). On May 7, 1973, three Least Terns were observed in Fish Harbor. By May 18, eighteen birds were observed, fourteen of which were in Fish Harbor, and four in the seaplane basin. They were observed performing what appeared to be courtship feeding at the end of May, and there was some hope that they might nest in the sandy area at station 73, since this is located between the two areas of occurrence. This area offered a small amount of suitable nesting habitat. Bulldozing in the potential area inhibited any nesting attempts, and the numbers gradually declined, until by the beginning of July, only one Least Tern was observed in the harbor (West Basin,L.A.). This is considered unfortunate, since the Least Tern is on the Endangered Species list and has suffered most severely from nesting-habitat destruction. This species was next seen in August, and then not again until May of 1974. The nesting area again was being bulldozed and no nesting took place, but in June, 1975 ten nests were found at station 73 with 20 potential nesting pairs seen in the vicinity.

Thalasseus elegans (Elegant Tern). One was observed on Cabrillo Beach late in May, 1973, and was seen in some numbers from August of 1973 to mid-November. It was then absent, with the exception of a single record in February, until late June. This species is found almost solely in the outer harbor.

Hydroprogne caspia (Caspian Tern). Observed first on May 14. It was observed sporadically from May to July, 1973 in small numbers, (from 2 to 11) at station 73 throughout the year, though only sporadically from early November, 1973 to May, 1974 and is absent in July.

ALCIDAE (Auks)

Uria aalge (Common Murre). One partly oiled Common Murre seen on February 26, March 25, and March 30, 1973, at the entrance to the main channel. Another was seen just inside the outer breakwater on May 25, and five more were seen near the entrance to Pier J. There was an additional sighting in February, 1974.

Endomychura hypoleuca (Xantus Murrelet). Two were seen on June 29, 1973, one near the marina opposite Holiday Harbor and one near the outer breakwater. These sightings are worthy of particular note, in that there are few, if any, coastal records for this species in the Los Angeles area.

Calypte anna (Anna's Hummingbird). One was seen feeding at station 58.

ALCEDINIDAE (Kingfishers)

Megaceryle alcyon (Belted Kingfisher). Found sporadically near the water in remote areas of West Basin (LA) in inlets near the main channel, in Pier J, and over Holiday Harbor. There have been a total of 18 sightings between February 5 and March 30, 1973. The species was absent from the harbor from mid-March to early August.

HIRUNDINIDAE (Swallows)

Hirundo rustica (Barn Swallow). These birds have been observed in almost all parts of the harbor from April to mid-July. Barn swallows are apparently nesting in all parts of the harbor except the outer breakwater - under docks, and under the eaves of buildings. Particular areas noted are in Pier J, among pilings supporting dock at north end of station 88, and in the Dominguez Slough.

Petrochelidon pyrrhonota (Cliff Swallow). Two pairs observed at Cabrillo Beach, feeding over the beach, and over a small freshwater pond above the beach. These birds were first seen in late March, 1973, and appeared to be using holes in the cliff above Cabrillo Beach and probably nested there. Also seen in the West Basin of the Long Beach Harbor. This species was seen again in August, 1973, but was not otherwise seen during the survey.

TYRANNIDAE (Tyrant Flycatchers)

Tyrannus verticalis (Western Kingbird). One bird seen on breakwater August 25, 1973.

Empidonas difficilis (Western Flycatcher). Two seen on one day of observation early May, 1973.

Contopus sordidulus (Western Wood Pewee). One seen on the breakwater on May 14, 1973.

VIREONIDAE (Vireos)

Vireo gilvus (Warbling Vireo). This is the most common member of its family in spring migration in southern California. Seen on two occasions during May 1 through May 18, 1973.

PARULIDAE (Wood Warblers)

Vermivora celata (Orange-crowned Warbler). Two seen on one day along the breakwater in early May, 1973.

Wilsonia pusilla (Wilson's Warbler). The most numerous spring migrant in southern California, seen on almost every day of observation during May 1 through May 18, 1973. This was the most numerous of the migrants observed on the breakwater. For example, on May 14, 1973, six Wilson's Warblers were seen. Seen here also on May 4, 1974.

Dendroica townsendi (Townsend's Warbler). Seen on one day of observation in early May, 1973.

Dendroica coronata (Yellow-rumped Warbler). Observed on the breakwater November 10, 1973.

FRINGILLIDAE (Finches)

Passerculus sandwichensis (Savannah Sparrow). One bird seen at station 62 on September 14, 1973. This bird was undoubtedly in migration.

ANALYSIS OF DISTRIBUTION

The bird species diversity of the harbor may be conveniently analyzed by grouping together stations with similar bird assemblages. The similarities are determined by the comparison of species and numbers of individuals occurring at the various stations. Once the similarity groups have been established, the occurrence of particular species and their relative numbers within selected similarity groups during the 14-month analysis period can be considered.

For the purpose of defining similar stations, three dates (December 8, 1973, September 7, 1973, and June 2, 1974) were selected and analyzed by the computer, individually and combined. The final analysis dealing with the three dates combined was found to be sufficiently similar to the three individual dates to yield a meaningful picture of the general avifaunal distribution in the harbor.

Dendrograms were constructed by computer indicating similarity in stations by species and numbers of birds observed, and similarity in species by stations where they were observed. These dendrograms were then plotted against each other, giving a table of similar stations versus similar species. Finally, similarity group lines, chosen to fall in a narrow similarity significance range, were drawn on each table to break the data into blocks representing groups of species that correlate with groups of stations. This is a general representation of species distribution in the harbor and though somewhat limited in that the analysis only covers three dates, nevertheless gives a fairly meaningful picture. Distribution and relative numbers of each species are figured in Table 8.1.. A map is also included (Figure 8.2) which indicates the major areas of similarity in the harbor.

The first group of stations (78, 63, 86, 73, 74, 56, and 82), though seemingly somewhat dissimilar in habitat, all share the fact that they are primarily composed of fairly large bodies of open water. Some are entirely open water such as 63 and 56. This grouping is verified by both the dendrogram and the actual species recorded at the stations. Stations 86 and 82, within the inner harbor, are found to be most similar to each other, along with station 78 which is in the outer harbor, but is relatively sheltered. Stations 56 and 63 are also similar to each other, each being comprised solely of open water. Station 74 is similar to 56 and 63 in that it is also an open water station, but it is separated from these two stations because it contains the sewer outfalls and apparently has some unique qualities in the species and numbers attracted to it. Stations 56 and 74 are also indicated in the behavior analysis presented later, as areas where a large percentage of the birds appearing there are feeding. Station 73 will be discussed later.

Group One stations are notable because relatively few species and relatively small numbers occur there. Forster's Tern and Bonaparte's Gull are the only species occurring in any numbers and both tend to prefer open water areas of the harbor for feeding. Both the Western and Heermann's Gull occur in this group but they are found throughout the harbor. More significant is the fact that they occur here in smaller numbers, which would seem to indicate that this group of stations is generally less desirable to avifauna. The fact that these areas are generally open water with less available shelter from wind may in part explain the paucity of birds.

Group Two includes only three stations (51, 69, and 91), which have little apparent similarity to each other in habitat. They are grouped, however, in that they are even more marked in the dearth of birds than the stations of Group One. The limited numbers of birds at station 51 may be attributable

Table 8.1. BIRD SPECIES SUMMED OVER TIME, LISTED BY STATION

	K50	K51	K52	K53	K54	K55	K56	K57	K58	K59	K60	K61	K62	K63	K64	K65	K66	K67	K68	K69	K70	K71	K72	K73
1. ACTITIS MACULARIA	1	7	1	1	5	2	0	3	0	0	0	0	0	0	2	2	0	2	0	0	2	17	1	0
2. AECHMOPHORUS OCCIDENTALIS	15	2	7	0	0	0	33	0	0	1	0	0	0	2	65	1	0	0	0	0	1	0	0	0
3. ANAS CYANOPTERA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	77
4. ANAS PLATYRHYNCHOS	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
5. ANATIDAE ANAS	0	0	0	0	0	0	0	0	1	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6. APHRIZA VIRGATA	3	0	66	0	0	0	2	1	12	11	0	0	20	0	0	0	0	0	0	12	11	7	1	0
7. ARDEA HERODIAS	3	0	0	2	1	2	1	1	3	7	17	0	19	0	0	0	0	0	4	0	2	4	2	5
8. ARENARIA INTERPRES	46	0	42	3	3	0	0	1	17	27	21	0	22	0	1	0	0	0	0	0	2	43	0	2
9. ARENARIA MELANOCEPHALA	0	0	57	1	0	0	4	6	50	96	54	16	50	5	2	0	0	0	0	0	2	17	1	0
10. AYTHYA AFFINIS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	80	3	0	0
11. BRANTA NIGRICANS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
12. BUTORIDES VIRESCENS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13. CALIDRIS ALBA	191	51	226	1	0	0	0	3	30	51	45	18	43	0	7	0	0	0	0	3	1	33	11	25
14. CALIDRIS ALPINA	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15. CALIDRIS MAURI	0	41	188	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
16. CALIDRIS MINUTILLA	0	7	2	0	0	0	0	0	0	2	2	1	0	0	1	0	0	0	0	0	29	27	1	0
17. CALYPTE ANNA	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18. CATOPTROPHORUS SEMIPALMATUS	78	30	51	7	0	0	3	11	17	13	12	4	36	0	18	2	0	0	4	5	4	76	0	0
19. CHARADRIUS ALEXANDRINUS	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
20. CHARADRIUS HIATICULA	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21. CHARADRIUS VOCIFERUS	30	4	2	2	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
22. CICONIIFORMES ARDEIDAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
23. CORVIDAE CORVUS	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24. DENDROICA CORONATA	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
25. EGRETTA THULA	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26. FALCO SPARVERIUS	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
27. FULICA AMERICANA	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0
28. GAVIA ARCTICA	0	1	0	1	0	0	7	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
29. GAVIA IMMER	0	0	2	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0
30. GAVIA STELL /A	1	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0
31. GAVIIDAE GAVIA	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
32. HETEROSCELUS INCANUS	0	0	0	0	0	0	0	0	0	0	0	2	14	0	1	0	0	0	0	0	1	15	2	0
33. HIRUNDO RUSTICA	0	0	0	4	0	3	0	0	14	2	11	0	0	0	0	0	0	0	0	1	0	0	0	0
34. HYDROPROGNE CASPIA	61	0	3	1	0	3	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	5	20
35. LARUS ARGENTATUS	0	4	4	2	3	6	3	16	83	24	30	4	49	2	20	32	13	1	0	1	0	62	1	0
36. LARUS CALIFORNICUS	815	203	189	57	62	224	3	4	2	1	1	26	3	1	1344	282	1549	54	0	2	20	0	1	0
37. LARUS CANUS	233	687	255	3	226	12	2	0	0	4	3	1	3	0	5	3	0	0	11	3	2	0	1	0
38. LARUS DELAWARENSIS	221	124	440	30	42	76	6	0	2	3	3	1	107	0	169	110	25	0	5	1	7	0	0	0
39. LARUS GLAUCESCENS	1	2	1	0	0	1	0	0	19	16	22	4	19	0	21	1	0	1	0	0	1	3	1	0
40. LARUS HEERMANNI	167	53	26	145	237	1384	97	928	1927	3447	2787	297	3844	278	2181	794	802	94	156	18	52	413	28	0
41. LARUS HYPERBOREUS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
42. LARUS OCCIDENTALIS	776	129	342	79	294	968	142	936	2263	781	1444	120	1238	43	1053	435	46	26	175	0	94	1856	31	9
43. LARUS PHILADELPHIA	968	234	15	0	19	0	19	2	6	52	98	67	63	67	6	3	0	50	84	46	35	12	23	17
44. LARUS THAYERI	0	0	0	0	0	0	0	2	1	1	0	0	0	0	3	0	0	0	0	0	0	0	0	3
45. LIMNODROMUS SCOLOPACEUS	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	7
46. LIMOSA FEDOA	11	1	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
47. MEGACERYLE ALCYON	1	0	1	1	7	3	0	0	0	0	0	0	0	0	3	1	0	0	1	0	0	0	0	0
48. MELANITTA DEGLANDI	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	4	4	0	0	0
49. MELANITTA NIGRA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	2	0	0	7	1	1	0	0	0
50. MELANITTA PERSPICILLATA	482	41	188	12	107	26	158	11	3	0	40	59	26	19	2595	217	0	12	1726	1920	2889	339	84	0
51. MERGUS MERGANSER	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52. MERGUS SERRATOR	0	0	0	7	1	3	13	0	1	0	1	0	3	0	0	0	0	0	0	3	0	0	0	0
53. NUMENIUS PHAEOPUS	3	1	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54. NYCTICORAX NYCTICORAX	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
55. OXYURA JAMAICENSIS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
56. PANDION HALIAETUS	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57. PASSERCULUS SANDWICHENSIS	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
58. PASSERIFORMES PARULIDAE	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
59. PELECANUS OCCIDENTALIS	2	1	0	2	1	1	42	72	686	536	439	44	716	7	3	0	0	1	2	0	28	435	25	0
60. PETROCHELIDON PYRRHONOTA	0	0	0	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61. PHALACROCORAX AURITUS	16	9	4	7	1	0	0	0	16	2	2	0	0	0	0	0	0	0	7	5	30	294	28	0
62. PHALACROCORAX PELAGICUS	0	0	0	0	0	1	2	1	1	0	0	0	2	0	2	0	0	1	3	0	0	1	0	0
63. PHALACROCORAX PENICILLATUS	0	0	0	0	0	1	0	0	0	3	1	1	4	0	3	0	0	0	5	1	0	3	0	0
64. PLUVIALIS SQUATAROLA	131	18	15	22	0	0	4	2	45	100	79	7	90	0	0	0	0	0	5	0	22	69	2	98
65. PODICEPS AURITUS	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
66. PODICEPS NIGRICOLLIS	11	0	14	0	38	7	0	0	2	0	0	3	0	0	0	0	0	0	0	0	0	29	5	0
67. PODILYMBUS PODICEPS	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
68. PUFFINUS GRISEUS	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
69. RISSA TRIDACTYLA	1	1	0	0	0	1	0	7	34	15	200	103	13	0	0	0	0	0	0	0	0	2	0	0
70. STERCORARIUS PARASITICUS	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
71. STERCORARIUS POMARINUS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
72. STERNA ALBIFRONS	2	0	4	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	38	0	0
73. STERNA FORSTERI	499	33	491	5	73	4	49	2	40	11	11	40	40	5	31	0	0	17	18	0	11	107	158	307
74. STERNA HIRUNDO	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75. THALASSEUS ELEGANS	27	7	20	0	17	2	1	0	0	0	1	0	0	1	1	0	0	0	0	0	0	10	0	91
76. TYRANNUS VERTICALIS	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
77. URIA AALGE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
78. WILSONIA PUSILLA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
79. CHARADRIIFORMES CHARADRIIDAE	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80. CHARADRIIFORMES LARIDAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 8.1. BIRD SPECIES SUMMED OVER TIME, LISTED BY STATION (cont'd)

	X74	X75	X76	X77	X78	X79	X80	X81	X82	X83	X84	X85	X86	X87	X88	X89	X90	X91	X92	X93	X94	X95	X96	X97
1. ACTITIS MACULARIA	0	0	3	0	3	0	1	0	1	1	1	3	1	3	0	0	2	0	2	4	0	0	0	0
2. AECHMOPHORUS OCCIDENTALIS	0	0	0	0	0	0	0	0	0	0	1	7	0	0	0	0	0	0	1	0	0	0	1	0
3. ANAS CYANOPTERA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4. ANAS PLATYRHYNCHOS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5. ANATIDAE ANAS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6. APHRIZA VIRGATA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7. ARDEA HERODIAS	0	0	0	0	0	1	1	0	0	0	0	0	1	0	1	0	0	0	1	0	1	0	0	0
8. ARENARIA INTERPRES	0	0	0	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
9. ARENARIA MELANOCEPHALA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10. AYTHYA AFFINIS	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	22	0
11. BRANTA NIGRICANS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12. BUTORIDES VIRESCENS	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
13. CALIDRIS ALBA	0	2967	0	0	3	0	0	0	0	0	0	0	0	4	0	0	0	3	0	0	0	0	0	0
14. CALIDRIS ALPINA	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15. CALIDRIS MAURI	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
16. CALIDRIS MINUTILLA	2	1	0	4	15	0	0	0	2	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0
17. CALYPTE ANNA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18. CATOPTROPHORUS SEMIPALMATUS	0	167	0	4	2	0	0	1	3	10	0	0	7	7	0	0	4	2	5	2	0	1	0	0
19. CHARADRIUS ALEXANDRINUS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20. CHARADRIUS HIATICULA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
21. CHARADRIUS VOCIFERUS	0	1	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22. CICONIIFORMES ARDEIDAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
23. CORVIDAE CORVUS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0	0	0
24. DENDROICA CORONATA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25. EGRETTA THULA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
26. FALCO SPARVERIUS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
27. FULICA AMERICANA	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0
28. GAVIA ARCTICA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29. GAVIA IMMER	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	6	0	0	0	0	0	1	0
30. GAVIA STELLATA	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31. GAVIIDAE GAVIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32. HETEROSCELUS INCANUS	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33. HIRUNDO RUSTICA	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
34. HYDROPROGNE CASPIA	1	0	3	5	2	0	4	2	0	4	0	3	1	0	0	0	3	0	0	0	0	0	1	3
35. LARUS ARGENTATUS	0	336	7	1	0	4	6	6	4	0	15	503	3	0	0	4	192	0	4	4	2	0	10	3
36. LARUS CALIFORNICUS	0	199	24	5	36	7	227	605	126	86	872	2597	376	181	186	379	186	3	172	41	66	95	1881	470
37. LARUS CANUS	0	6	2	1	1	0	28	7	2	4	16	10	12	6	3	6	3	0	1	0	4	1	12	1
38. LARUS DELAWARENSIS	0	1783	13	4	2	7	55	90	19	61	26	92	40	84	47	67	84	5	7	19	50	4	140	29
39. LARUS GLAUCESCENS	0	34	0	0	0	1	3	0	1	1	1	6	1	1	0	0	37	0	1	0	1	0	31	1
40. LARUS HEERMANNI	37	230	178	802	282	540	573	519	236	432	134	378	61	129	260	583	135	27	437	189	382	126	3373	806
41. LARUS HYPERBOREUS	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42. LARUS OCCIDENTALIS	1	1698	826	968	163	689	949	190	125	219	682	1541	138	227	386	665	2163	201	744	326	157	103	2189	317
43. LARUS PHILADELPHIA	511	486	0	36	16	1	18	74	46	4	12	83	0	0	4	29	23	0	61	3	18	28	210	62
44. LARUS THAYERI	0	4	0	0	0	0	0	0	0	0	1	0	1	0	0	0	3	0	0	0	0	0	0	0
45. LIMNODROMUS SCOLOPACEUS	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46. LIMOSA FEDOA	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47. MEGACERYLE ALCYON	0	0	0	0	0	2	0	2	0	1	1	1	1	0	3	1	2	0	0	1	0	0	1	0
48. MELANITTA DEGLANDI	0	0	4	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3
49. MELANITTA NIGRA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50. MELANITTA PERSPICILLATA	0	247	12	63	186	4	22	1	0	0	0	4	0	0	0	0	0	0	0	0	0	0	82	78
51. MERGUS MERGANSER	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52. MERGUS SERRATOR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53. NUMENIUS PHAEOPUS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54. NYCTICORAX NYCTICORAX	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
55. OXYURA JAMAICENSIS	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	1	0	0	0	1	0
56. PANDION HALIAETUS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57. PASSERCULUS SANDWICHENSIS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
58. PASSERIFORMES PARULIDAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
59. PELECANUS OCCIDENTALIS	18	35	3	5	12	0	2	1	0	0	0	0	5	0	0	1	0	0	0	0	0	0	1	0
60. PETROCHELIDON PYRRHONOTA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61. PHALACROCORAX AURITUS	2	5	2	1	2	2	5	0	0	1	78	16	5	2	4	3	1	0	13	0	0	0	3	2
62. PHALACROCORAX PELAGICUS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
63. PHALACROCORAX PENICILLATUS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
64. PLUVIALIS SQUATAROLA	0	55	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0
65. PODICEPS AURITUS	0	0	0	0	0	1	1	0	2	13	0	2	2	0	0	0	0	0	0	0	0	0	0	0
66. PODICEPS NIGRICOLLIS	0	7	1	0	1	0	11	4	2	21	0	11	1	0	0	4	12	0	2	0	0	0	1	0
67. PODILYMBUS PODICEPS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
68. PUFFINUS GRISEUS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
69. RISSA TRIDACTYLA	0	1	0	0	4	0	1	1	1	4	0	1661	0	5	1	0	0	0	0	0	0	0	0	0
70. STERCORARIUS PARASITICUS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
71. STERCORARIUS POMARINUS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
72. STERNA ALBIFRONS	0	0	3	11	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
73. STERNA FORSTERI	44	50	5	22	64	0	30	41	11	28	200	46	10	1	4	30	7	0	2	0	12	3	78	13
74. STERNA HIRUNDO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75. THALASSEUS ELEGANS	0	0	0	7	3	0	7	10	0	7	65	1	5	0	2	0	0	0	0	0	1	0	0	0
76. TYRANNUS VERTICALIS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
77. URIA AALGE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
78. WILSONIA PUSILLA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
79. CHARADRIIFORMES CHARADRIIDAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80. CHARADRIIFORMES LARIDAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 8.2. BIRD SPECIES LIST BY TIME STATIONS SUMMED

	7308	7309	7310	7311	7312	7401	7402	7403	7404	7405	7406	7407	7408	7409
1. ACTITIS MACULARIA	2	15	6	0	12	0	0	7	2	1	0	0	2	0
2. AECHMOPHORUS OCCIDENTALIS	16	7	7	49	39	4	10	7	0	1	0	0	0	2
3. ANAS CYANOPTERA	0	0	0	0	0	77	0	0	0	0	0	0	0	0
4. ANAS PLATYRHYNCHOS	0	0	0	0	0	0	0	0	3	0	0	0	0	0
5. ANATIDAE ANAS	0	0	0	0	0	0	21	0	0	0	0	0	0	0
6. APHRIZA VIRGATA	15	5	2	7	2	16	5	13	80	1	4	2	0	1
7. ARDEA HERODIAS	5	21	10	15	10	0	1	0	0	0	0	1	0	0
8. ARENARIA INTERPRES	23	19	21	22	32	24	12	40	27	0	0	0	5	24
9. ARENARIA MELANOCEPHALA	31	42	17	16	37	30	25	19	57	3	2	0	14	27
10. AYTHYA AFFINIS	0	0	0	1	15	34	15	49	0	0	0	0	0	0
11. BRANTA NIGRICANS	0	0	0	0	0	0	0	1	0	0	0	0	0	0
12. BUTORIDES VIRESCENS	0	3	0	0	0	0	0	0	0	0	0	0	0	0
13. CALIDRIS ALBA	0	13	380	116	1095	600	710	659	153	10	0	0	0	7
14. CALIDRIS ALPINA	0	0	0	0	0	0	0	0	2	4	0	0	0	0
15. CALIDRIS MAURI	0	0	0	0	42	4	2	63	147	3	0	0	0	1
16. CALIDRIS MINUTILLA	19	16	26	4	1	3	7	3	0	0	0	0	1	19
17. CALYPTE ANNA	0	0	0	0	0	0	0	0	0	0	1	0	0	0
18. CATOPTROPHORUS SEMIPALMATUS	2	42	70	67	113	119	40	134	19	2	1	0	1	24
19. CHARADRIUS ALEXANDRINUS	4	0	0	5	0	0	1	0	0	0	0	0	0	0
20. CHARADRIUS HIATICULA	1	0	0	0	3	0	0	0	0	0	0	0	0	0
21. CHARADRIUS VOCIFERUS	7	4	0	0	24	6	4	2	0	0	2	0	0	0
22. CICONIIFORMES ARDEIDAE	0	1	0	0	0	0	0	0	0	0	0	0	0	0
23. CORVIDAE CORVUS	0	0	0	3	1	0	0	0	0	0	0	0	1	0
24. DENDROICA CORONATA	0	0	0	3	0	0	0	0	0	0	0	0	0	0
25. EGRETTA THULA	0	1	0	0	1	0	0	0	0	0	0	0	0	0
26. FALCO SPARVERIUS	1	0	0	1	0	0	0	1	0	0	0	0	0	0
27. FULICA AMERICANA	0	3	0	0	1	0	0	0	0	0	0	0	0	2
28. GAVIA ARCTICA	5	0	0	1	1	2	1	1	0	0	0	0	0	0
29. GAVIA IMMER	5	0	0	0	4	2	0	1	0	0	0	11	0	0
30. GAVIA STELLATA	3	4	0	1	0	2	4	1	0	0	2	7	1	2
31. GAVIIDAE GAVIA	0	0	0	1	1	0	0	0	0	0	0	0	0	0
32. HETEROSCELUS INCANUS	2	6	6	1	7	11	5	3	2	4	0	3	1	1
33. HIRUNDO RUSTICA	0	27	0	0	0	0	0	0	5	0	0	1	0	4
34. HYDROPROGNE CASPIA	22	37	5	0	30	10	0	3	0	3	7	0	4	30
35. LARUS ARGENTATUS	36	1	480	54	301	116	145	164	63	14	22	1	12	36
36. LARUS CALIFORNICUS	3	866	895	2960	2900	2034	515	860	700	409	88	0	34	393
37. LARUS CANUS	0	0	1	5	159	364	687	323	11	0	0	0	0	0
38. LARUS DELAWARENSIS	10	207	481	250	601	799	824	710	30	141	1	112	23	105
39. LARUS GLAUCESCENS	0	1	1	5	142	20	32	33	2	4	2	0	0	1
40. LARUS HEERMANNI	1922	10193	3796	1560	363	640	250	290	3	5	1123	1083	3007	5896
41. LARUS HYPERBOREUS	0	0	0	0	0	4	2	0	0	0	0	2	0	1
42. LARUS OCCIDENTALIS	490	3840	4411	2006	3713	1390	1045	1738	602	1301	2718	402	889	3605
43. LARUS PHILADELPHIA*	0	0	0	727	1977	719	150	213	100	50	16	0	0	0
44. LARUS THAYERI	0	0	0	0	4	3	1	1	2	3	0	0	0	0
45. LIMNODROMUS SCOLOPACEUS	1	0	0	0	0	14	0	6	0	0	0	0	0	0
46. LIMOSA FEDOA	1	0	1	0	0	7	3	19	10	0	0	1	0	1
47. MEGACERYLE ALCYON	3	3	5	3	3	7	1	1	0	0	0	0	2	6
48. MELANITTA DEGLANDI	0	0	0	3	0	5	1	7	2	0	0	0	0	3
49. MELANITTA NIGRA	0	0	0	1	12	1	1	0	1	0	0	0	0	0
50. MELANITTA PERSPICILLATA	7	0	86	311	4015	2812	1420	1720	340	129	83	96	29	11
51. MERGUS MERGANSER	0	0	0	0	0	0	0	0	0	0	2	0	0	0
52. MERGUS SERRATOR	0	0	0	2	6	0	2	20	4	0	0	0	1	0
53. NUMENIUS PHAEOPUS	0	0	0	1	0	3	0	1	2	0	0	0	0	0
54. NYCTICORAX NYCTICORAX	1	1	0	0	0	0	0	0	0	0	0	0	0	0
55. OXYURA JAMAICENSIS	0	1	12	0	0	0	0	0	0	1	0	0	0	0
56. PANDION HALIAETUS	1	0	0	0	0	0	0	0	1	0	0	0	0	0
57. PASSERCULUS SANDWICHENSIS	0	1	0	0	0	0	0	0	0	0	0	0	0	0
58. PASSERIFORMES PARULIDAE	0	1	0	0	0	0	0	0	0	0	0	0	0	0
59. PELECANUS OCCIDENTALIS	384	312	47	217	21	17	1	10	3	78	314	244	202	1256
60. PETROCHELIDON PYRRHONOTA	2	0	0	0	0	0	0	0	0	0	0	0	0	0
61. PHALACROCORAX AURITUS	24	130	140	23	73	34	10	15	0	1	5	1	3	71
62. PHALACROCORAX PELAGICUS	0	0	0	3	3	1	0	3	0	1	0	0	0	0
63. PHALACROCORAX PENICILLATUS	6	5	5	2	3	0	0	1	0	1	0	0	0	6
64. PLUVIALIS SQUATAROLA	5	33	61	113	130	209	85	91	0	20	5	4	5	80
65. PODICEPS AURITUS	0	0	0	2	0	13	2	0	0	0	0	0	0	0
66. PODICEPS NIGRICOLLIS	0	6	33	20	67	54	17	20	15	1	0	0	0	6
67. PODILYMBUS PODICEPS	0	0	0	2	0	1	0	0	0	0	0	0	0	0
68. PUFFINUS GRISEUS	0	0	0	0	1	0	0	0	0	0	0	0	0	0
69. RISSA TRIDACTYLA	0	0	0	0	11	7	1630	242	10	42	49	17	3	2

Table 8.2. BIRD SPECIES LIST BY TIME STATIONS SUMMED (cont'd)

	7308	7309	7310	7311	7312	7401	7402	7403	7404	7405	7406	7407	7408	7409
70. STERCORARIUS PARASITICUS	0	0	2	1	0	0	0	0	6	0	0	0	2	0
71. STERCORARIUS POMARINUS	0	0	0	0	0	0	0	0	0	0	0	0	0	1
72. STERNA ALBIFRONS	0	0	0	0	0	0	0	0	0	25	23	4	3	1
73. STERNA FORSTERI	429	761	240	49	28	51	41	384	29	99	9	17	117	472
74. STERNA HIRUNDO	0	0	0	0	0	3	1	0	0	0	0	0	0	0
75. THALASSEUS ELEGANS	6	18	5	60	0	0	1	0	9	0	0	0	0	196
76. TYRANNUS VERTICALIS	0	0	0	0	0	0	0	0	0	0	0	0	1	0
77. URIA AALGE	0	0	0	0	0	0	5	0	0	0	0	0	0	0
78. WILSONIA PUSILLA	0	0	0	0	0	0	0	0	0	1	0	0	0	0
79. CHARADRIIFORMES CHARADRIIDAE	2	0	0	0	0	0	0	0	0	0	0	0	0	0
80. CHARADRIIFORMES LARIDAE	10	0	0	0	0	0	0	0	0	0	0	0	0	0

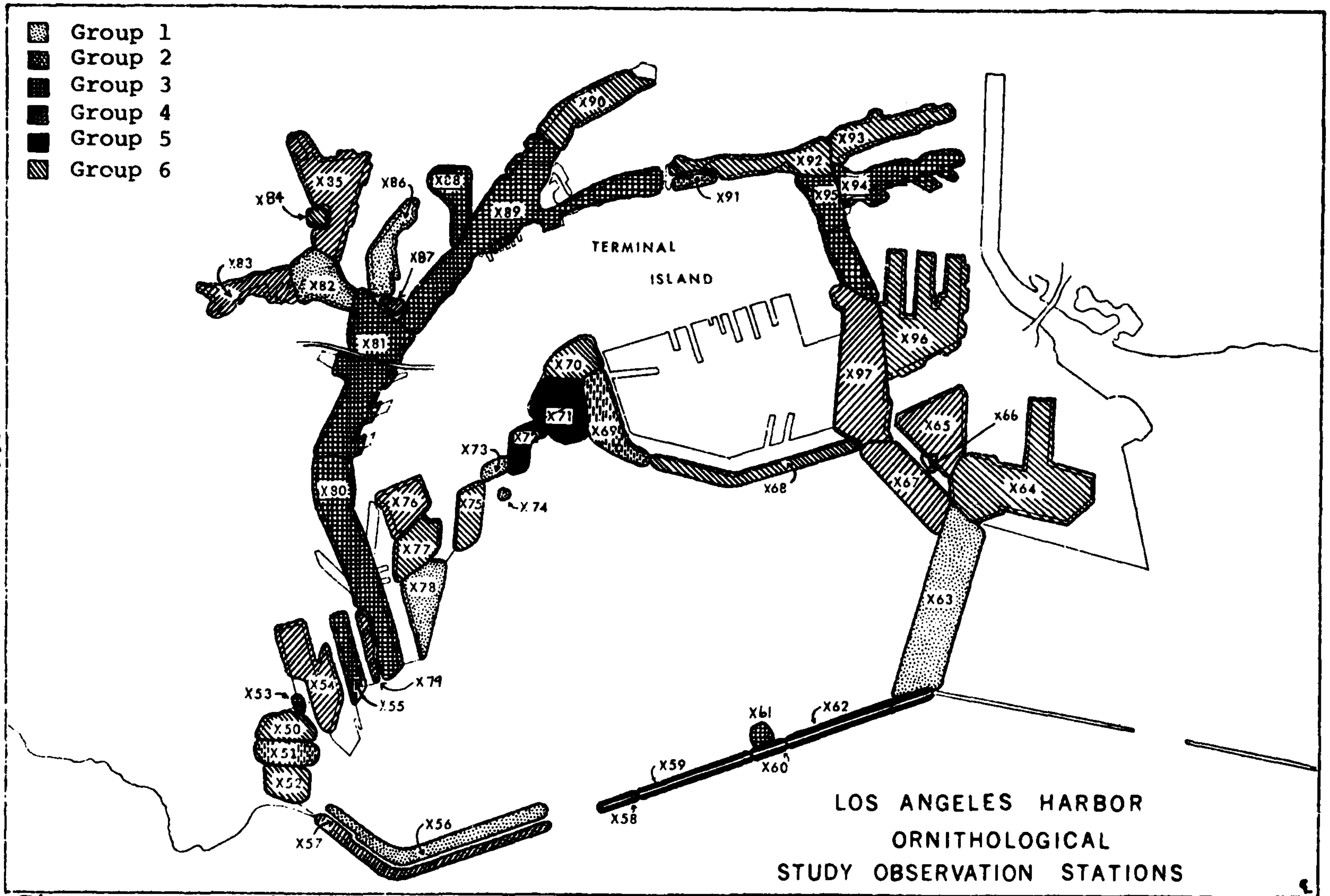


Figure 8.2. Species Groups by Stations.

to human influence, as this station includes a public boat-launching ramp. Counts were, for the most part, conducted on weekends when the use of this area would be heaviest. Though the areas on either side of 51 were also subject to public use, they tended to have far greater variety and numbers of birds and the only apparent difference between station 51 and its neighbors is the presence of the boat-launching ramp. Station 91 is a section of rock along a marina in Cerritos Channel and is also subject to human influence. Conversely, station 69 has little public usage, but it is often a turbulent area with little to block the full force of the winds. The seawall there seems to be barren, perhaps because of its western exposure, and consequently it supports little bird life. Most of the birds seen in these areas are in transit, making little use of the stations.

Group Three is composed of a fairly large number of stations and, with the exceptions of stations 53, 55, and 61, are all channels in the inner harbor. Station 61 is the most exposed of the stations, and within this group is somewhat different because the bait barge is the main attraction. This group of stations attracts large congregations of gulls almost exclusively, with very few other species present. Station 53 is probably clustered in this grouping because it accomodates the gull flocks driven from station 50 by human use, and is otherwise usually devoid of bird life. The Forster's Tern and Brown Pelican are the only non-gull species occurring in any numbers at these stations. While the tern will feed in most areas of the harbor, the Pelican is found primarily near the bait barge. This group of stations includes some of the least desirable areas in the harbor for bird life.

Group Four also comprises a fairly large group of stations which are again marked by concentrations of gulls. Both the Bonaparte's Gulls and Forster's Terns are notably absent, while the Herring Gull is present at most of the stations. The majority of these stations lie within the inner harbor or, like 54, are relatively sheltered. All but station 57 and 79 offer fairly large bodies of water for roosting or feeding. Stations 57, 79, and 87 are all roosting places for large numbers of gulls. In addition, 57 is the only one of these stations which accomodates any of the shorebirds. It is interesting to note the difference between 57 and other sections of the breakwater. The smaller number of gulls is attributable to public access to the breakwater. The limited number and variety of shorebirds may be due partly to human use, but also to the structure of the breakwater with its vertical sides, which provides less feeding surface than the broken rock of the middle breakwater.

The major features in Group Five stations are primarily broken rock breakwaters to which human access is limited or nonexistent. This group contains the greatest variety of

shorebirds, and many are found in substantial numbers. One of the greatest concentrations of Heermann's Gulls also occurs here. Stations in this group have high percentages of roosting birds, which indicates the importance of isolated breakwater areas for the large roosting group, primarily gulls. The shorebirds found here are almost all feeding. While Ring-billed and California Gulls are almost totally absent, Western and Heermann's Gulls are numerous at these stations. Most other gulls are found only in relatively small numbers. Bonaparte's Gulls and Forster's Terns when found at these stations are almost always feeding rather than roosting. Kittiwakes are found in near maximum numbers at these stations, particularly 60.

Group Five stations seem to be particularly important as roosting areas for most of the marine members of the family Laridae, as well as for those Pelecaniformes occurring in the harbor. Those gulls which avoid these areas are all species which are usually marine only in non-nesting seasons, and the rocky environment is not appealing to them.

Group Six is another fairly large group without the consistency in habitat found in some of the other groups. Stations 50, 52 and 75 are the only areas of sandy beach in the harbor and are ranked together. Several species show a marked preference for sandy beach, particularly at station 75, with maximum numbers of six species occurring at two of the three stations. Station 52 is different from these other two areas in that it includes a public swimming beach. Even with this handicap, some species do occur there in large numbers. The three stations also seem to attract most of the shorebird species though not necessarily in the numbers found in the previous group. Four of the stations are found in the inner harbor, and the major populations there are gulls. Station 64, though not actually in the inner harbor, is very similar in habitat, as evidenced by the large number of California Gulls which are usually found in greatest numbers in the inner harbor. Station 64 is also one of the best areas in the harbor for Surf Scoters, along with station 68. Although station 64 is quite sheltered and station 68 is not, these areas are relatively undisturbed by human presence. The stations in Group Six have the greatest variety of species; however, 15 out of the 18 species found there were found in the three stations with sand beach emphasizing the attraction of relatively natural habitat.

In summary, the tabular data reveal some fairly clear-cut distribution patterns for the harbor avifauna. Gulls are numerically the dominant species, but only two are well distributed throughout the harbor, the Western and Heermann's Gulls. The California Gulls show a marked preference for the inner harbor as do the Glaucous-winged Gulls, but all the gull species except these two last mentioned are attracted

to the sandy areas of the harbor. The protected breakwaters are where all the major concentrations of shorebirds are found, although the shorebirds are also attracted to the sandy areas to a lesser extent. The terns also seem to prefer the outer harbor, although the Forster's Tern is found in most of the stations. The factors which seem to be of the greatest importance in attracting both a variety and a number of birds include the availability of relatively natural habitat, and the relative freedom from human disturbance.

ANALYSIS OF SEASONALITY

The harbor is a large, complex area, and analysis of bird populations, distribution and seasonality must include examination in detail of selected areas in the harbor. Selected stations or groups of stations have been chosen for analysis of seasonality. These include representative areas within the harbor, and data for them have been handled in the following manner. First, for each area, Bray-Curtis dendrograms were constructed by computer to indicate similarity dates, by species and numbers of birds observed, and similarity in species by dates and numbers observed. These dendrograms were then plotted against each other, giving a two-way table of similar dates versus similar species. Finally, similarity group lines, chosen to fall in a narrow similarity significance range, were drawn on each table to break the data into blocks, representing groups of species that correlate with groups of dates. This gave a representation of seasonality and abundance at each station.

Table 8.2 presents seasonal data tabulated by year and month. A fair estimate of the seasonal occurrence of the species at representative stations can thus be made. The following section summarizes these data, as shown in Tables 8.3A-8.3M.

Station X51 is the narrow, short, rock breakwater and dock area of the public boat launching area plus the adjacent beach and open water south of the public swimming beach. The area is sparsely populated by a number of species, only a few of which occur with much regularity.

The first two species similarity groups consist of seven species sighted infrequently in the winter, and of these seven species, only the Double-crested Cormorant occurs in significant numbers.

Group Three contains birds seen on scattered dates in the fall, winter and spring. The Surf Scoter is the one species which occurs in significant numbers throughout the period, possibly because it is less subject to disturbance by human use. The Bonaparte's Gull is the only species which occurs in near maximum numbers, but that was on a single date and it is absent for most of the rest of the survey period. This indicates that the species is driven to using the area during its peak period, when there is the most competition for roosting space in the harbor. However, this species does not use the area on most occasions, even when its population is at maximum numbers in the harbor, and its absence is probably due to human presence.

Group Four includes six species that occur with

HARBOR PROJECTS, AHF, USC

BIRD SPECIES LIST BY TIME STATIONS SUMMED

	7308	7309	7310	7311	7312
1. ACTITIS MACULARIA	2	15	6	8	12
2. AECHMORPHORUS OCCIDENTALIS	16	7	7	49	39
3. ANAS CYANOPTERA	0	0	0	0	9
4. ANAS PLATYRHYNCHOS	0	0	0	0	0
5. ANATIDAE ANAS	0	0	0	0	0
6. APHRIZA VIRGATA	15	5	2	7	2
7. ARDEA HERODIAS	5	21	10	15	10
8. ARENARIA INTERPRES	23	19	21	22	32
9. ARENARIA MELANOCEPHALA	31	42	17	16	37
10. AYTHYA AFFINIS	0	0	0	1	15
11. BRANTA NIGRICANS	0	0	0	0	0
12. BUTORIDES VIRESCENS	0	3	0	0	0
13. CALIDRIS ALBA	0	13	359	116	1055
14. CALIDRIS ALPINA	0	0	0	0	0
15. CALIDRIS MAURI	0	0	0	0	42
16. CALIDRIS MINUTILLA	19	16	26	4	1
17. CALYPTE ANNA	0	0	0	0	0
18. CATOPTROPHORUS SEMIPALMATUS	2	42	70	47	113
19. CHARADRIUS ALEXANDRINUS	4	0	0	5	0
20. CHARADRIUS HIATICULA	1	0	0	0	3
21. CHARADRIUS VOCIFERUS	7	4	0	0	24
22. CICONIIFORMES ARDEIDAE	0	1	0	0	0
23. CORVIDAE CORVUS	0	0	0	3	1
24. DENDROICA CORONATA	0	0	0	3	0
25. EGRETTA THULA	0	1	0	0	1
26. FALCO SPARVERIUS	1	0	0	1	0
27. FULICA AMERICANA	0	3	0	0	1
28. GAVIA ARCTICA	5	0	0	1	1

HARBOR PROJECTS, AHF, USC

BIRD SPECIES LIST BY TIME STATIONS SUMMED

	7401	7402	7403	7404	7405	7406	7407	7408	7409
1.	8	9	7	2	1	0	0	2	8
2.	4	10	7	0	1	0	0	0	2
3.	77	0	0	0	0	0	0	0	0
4.	0	0	0	3	0	0	0	0	0
5.	0	21	0	0	0	0	0	0	0
6.	16	5	13	89	1	4	2	0	1
7.	8	1	6	0	0	0	1	0	0
8.	24	12	40	27	0	0	0	5	24
9.	38	25	19	57	3	2	4	14	27
10.	34	15	49	0	0	0	0	0	0
11.	0	0	1	0	0	0	0	0	0
12.	0	0	0	0	0	0	0	0	0
13.	608	710	659	153	10	0	0	0	7
14.	0	0	0	2	4	0	0	0	0
15.	4	2	63	147	3	0	0	0	1
16.	3	7	3	0	0	0	8	1	19
17.	0	0	0	0	0	1	0	0	0
18.	119	40	134	19	2	1	8	1	24
19.	0	1	0	0	0	0	0	0	0
20.	0	0	0	0	0	0	0	0	0
21.	6	4	2	0	0	2	0	0	0
22.	0	0	0	0	0	0	0	0	0
23.	0	0	0	0	0	0	0	1	0
24.	0	0	0	0	0	0	0	0	0
25.	0	0	0	0	0	0	0	0	0
26.	0	0	1	0	0	0	0	0	0
27.	0	0	0	0	0	0	0	0	2
28.	2	1	1	0	0	0	0	0	0

Table 8.2. Seasonal Occurrence and Abundance by Year and Month.

HARBOR PROJECTS, AHF, USC

BIRD SPECIES LIST BY TIME STATIONS SUMMED

	7308	7309	7310	7311	7312
29. GAVIA IMMER	5	0	0	0	4
30. GAVIA STELLATA	3	4	0	1	0
31. GAVIIDAE GAVIA	0	0	0	1	1
32. HETEROSCELUS INCANUS	2	6	6	1	7
33. HIRUNDO RUSTICA	0	27	0	0	0
34. HYDROPROGNE CASPIA	22	37	5	9	30
35. LARUS ARGENTATUS	34	1	440	54	301
36. LARUS CALIFORNICUS	3	866	895	2960	2908
37. LARUS CANUS	0	0	1	5	159
38. LARUS DELAWARENSIS	18	207	481	250	681
39. LARUS GLAUCESCENS	0	1	1	5	142
40. LARUS HEERMANNI	1922	10103	3756	1560	363
41. LARUS HYPERBOREUS	0	0	0	0	0
42. LARUS OCCIDENTALIS	458	3848	4411	2086	3711
43. LARUS PHILADELPHIA	0	0	0	727	1577
44. LARUS THAYERI	0	0	0	0	4
45. LIMNODROMUS SCOLOPACEUS	1	0	0	0	0
46. LIMOSA FEDOA	1	0	1	0	0
47. MEGACERYLE ALCYON	3	3	5	3	3
48. MELANITTA DEGLANDI	0	0	0	3	8
49. MELANITTA NIGRA	0	0	0	1	12
50. MELANITTA PERSPICILLATA	7	0	26	311	4915
51. MERGUS MERGANSER	0	0	0	0	0
52. MERGUS SERRATOR	0	0	0	2	4
53. NO-SPECIES *	0	0	0	0	0
54. NUMENIUS PHAEOPUS	0	0	0	1	0
55. NYCTICORAX NYCTICORAX	1	1	0	0	C
56. OXYURA JAMAICENSIS	0	1	12	0	0

HARBOR PROJECTS, AHF, USC

BIRD SPECIES LIST BY TIME STATIONS SUMMED

	7401	7402	7403	7404	7405	7406	7407	7408	7409
29.	2	0	1	0	0	8	11	9	9
30.	2	4	1	0	0	2	7	1	2
31.	0	0	0	0	0	0	0	0	0
32.	11	5	3	2	4	0	3	1	1
33.	0	0	0	5	8	6	1	0	4
34.	18	0	3	0	3	7	0	4	30
35.	116	145	164	63	14	22	1	12	36
36.	2834	515	860	708	489	89	0	34	393
37.	364	687	323	11	0	0	0	0	0
38.	739	524	710	35	141	1	112	23	105
39.	20	32	33	2	4	2	0	0	1
40.	440	258	298	1	5	1121	1983	3097	5396
41.	4	2	0	0	0	0	2	0	1
42.	1050	1045	1738	602	1201	2715	492	859	3645
43.	719	158	213	190	50	14	0	0	0
44.	3	1	1	2	3	5	0	0	0
45.	14	0	4	0	0	0	0	0	0
46.	7	3	19	10	0	0	1	0	1
47.	7	1	1	0	0	0	0	2	6
48.	5	1	7	2	0	0	4	0	3
49.	1	1	0	1	0	0	0	0	0
50.	2512	1420	1720	340	125	83	56	25	11
51.	0	0	0	0	0	2	0	0	0
52.	8	2	28	4	0	0	0	1	0
53.	0	0	0	0	0	0	0	0	0
54.	3	0	1	2	0	0	0	0	0
55.	0	0	0	0	0	0	0	0	0
56.	0	0	0	0	1	0	0	0	0

Table 8.2 (continued).

HARBOR PROJECTS, AHF, USC

BIRD SPECIES LIST BY TIME STATIONS SUMMED

	7308	7309	7310	7311	7312
57. PANDION HALIAETUS	1	0	0	0	0
58. PASSERCULUS SANDWICHENSIS	0	1	0	0	0
59. PASSERIFORMES PARULIDAE	0	1	0	0	0
60. PELECANUS OCCIDENTALIS	324	312	47	217	21
61. PETROCHELIDON PYRRHONOTA	2	0	0	0	0
62. PHALACROCORAX AURITUS	24	136	140	23	73
63. PHALACROCORAX PELAGICUS	0	0	0	3	3
64. PHALACROCORAX PENICILLATUS	4	5	5	2	3
65. PLUVIALIS SQUATAROLA	5	33	41	113	130
66. PODICEPS AURITUS	0	0	0	2	6
67. PODICEPS NIGRICOLLIS	0	6	33	29	57
68. PODILYMBUS PODICEPS	0	0	0	2	0
69. PUFFINUS GRISEUS	0	0	0	0	1
70. RISSA TRIDACTYLA	0	0	0	0	11
71. STERCORARIUS PARASITICUS	0	0	2	1	0
72. STERCORARIUS POMARINUS	0	0	0	0	0
73. STERNA ALBIFRONS	8	0	0	0	0
74. STERNA FORSTERI	429	761	240	49	28
75. STERNA HIRUNDO	0	0	0	0	0
76. THALASSEUS ELEGANS	6	18	5	60	0
77. TYRANNUS VERTICALIS	0	0	0	0	0
78. URIA AALGE	0	0	0	0	0
79. WILSONIA PUSILLA	0	0	0	0	0
80. CHARADRIIFORMES CHARADRIIDAE	2	0	0	0	0
81. CHARADRIIFORMES LARIDAE	10	0	0	0	0

HARBOR PROJECTS, AHF, USC

BIRD SPECIES LIST BY TIME STATIONS SUMMED

	7401	7402	7403	7404	7405	7406	7407	7408	7409
57.	0	0	0	1	0	0	0	0	0
58.	0	0	0	0	0	0	0	0	0
59.	0	0	0	0	0	0	0	0	0
60.	17	1	10	3	70	314	244	202	1256
61.	0	0	0	0	0	0	0	0	0
62.	34	18	15	0	1	5	1	3	71
63.	1	0	3	0	1	0	0	0	0
64.	0	0	1	0	1	0	0	0	6
65.	205	85	91	8	20	5	4	5	59
66.	13	2	0	0	0	0	0	0	0
67.	54	17	20	15	1	0	0	0	4
68.	1	0	0	0	0	0	0	0	0
69.	0	0	0	0	0	0	0	0	0
70.	7	1630	242	18	42	49	17	3	2
71.	0	0	0	0	0	0	0	2	0
72.	0	0	0	0	0	0	0	0	1
73.	0	0	0	0	25	23	4	3	1
74.	51	41	384	29	99	9	17	117	472
75.	3	1	0	0	0	0	0	0	0
76.	0	1	0	0	0	9	0	5	196
77.	0	0	0	0	0	0	0	1	0
78.	0	5	0	0	0	0	0	0	0
79.	0	0	0	0	1	0	0	0	0
80.	0	0	0	0	0	0	0	0	0
81.	0	0	0	0	0	0	0	0	0

Table 8.2 (continued).

Year	74	74	74	74	74	74	74	74	74	73	74	74	73	74	74	74	74	74	73	73	7777777777777 3333333444444	73	74	73	74	74	74	73	73	
Month	07	09	06	09	06	06	03	05	04	09	05	01	08	02	03	02	03	02	09	11	0001111100000 8990002467889	11	03	12	01	01	09	12	12	
Day	14	29	30	02	02	23	30	04	20	29	18	19	10	23	09	02	22	16	14	03	1020120212022 7726378768452	10	16	01	05	26	08	22	29	
Aechmorphorus occidentalis																									-					
Charadrius vociferus																									-					
Phalacrocorax auritus																			-						+	+				I
Gavia arctica																										-				
Melanitta deglandi																										-				
Calidris minutilla																											-			
Pelecanus occidentalis																											-			II
Actitis macularia																			-	+										
Falco sparverius																				-										
Larus philadelphia												.												.				*		
Melanitta perspicillata												+					+					-		-	+			+	-	III
Calidris mauri																								-						
Limosa fedoa																	-													
Limnodromus scolopaceus													-																	
Numenius phaeopus																						-								
Thalasseus elegans																						-								
Hydroprogne caspia																						+	-							
Arenaria interpres																						+				-	+			IV
Pluvialis squatarola																						+			-		-			
Catoptrophorus semipalmatus										-												*	-	-	-	-				
Larus glaucescens												-																		
Rissa tridactyla												-																		
Larus argentatus							-	+	-			+																		
Sterna forsteri							+	+	-				-										-							
Larus heermanni	-	-	-	-						+		+		-								-		-						V
Larus occidentalis	-	-			-	-	+	+	-	+	+	+	-									+		-			-			
Calidris alba							+			+		+		-	-							+	-		+					
Larus californicus							.	.	*	-	-	+				-						+	-					-		
Larus delawarensis								-	+	+	+	+	-		.	-	-			+				.	-					
Larus canus									-			+		.	.	*	-	+					-							

Table 8.3A. Station X51.
Relative abundance: * > + > (blank)>->. No symbol = mean value.
Sample date: 731229 indicates December 29, 1973.

	Group 1	Group 2	Group 3	Group 4	
Year	77777	777777777777777	7777777777777777777	777	
	44444	444433344434333	3334334444444343443	444	
Month	00000	000000000010000	1110110000000101001	000	
	66658	687799999909988	0101121133232222352	344	
Day	01212	302101202012211	0122020101201000202	322	
	26385	048474289232907	6076395996326128242	007	
Charadrius hiaticula		`              -`			
Sterna albifrons	`   - `	`              -`			
Charadrius alexandrinus		`              -`	`    +`		I
Podiceps auritus			`    -`		
Larus delawarensis	`   .-`	` +- +++  +-. --`	`++*++--+--+-+-- -+ `	`.--`	
Larus occidentalis	`-----`	`+--++++-++-+.+`	`++++-+--+---+-.--++`	`+-`	
Pluvialis squatarola		`+-----    -----`	`++++-++**-++-----++`	`  -`	
Calidris alba		`    .  - -+--  `	`--+++-+-+-+--  -- -`	`+*+`	
Melanitta perspicillata	`  - .`	`-..        -   `	` -.++++++++++-+++-.`	`+--`	
Arenaria interpres		` -  -+      - +`	`---- +--+ +- -  +  `	` + `	
Sterna forsteri	`   -.`	`    +*+--. .-++`	`- ----+++---    +  `	`+--`	
Catoptrophorus semipalmatus		`--- +- +-      `	`- ++-+-+  -- -- ---`	`+`	II
Larus heermanni		`++--+--+++    -`	`--+---++-  ---`		
Larus californicus	`   .-`	`     ---.-  .  `	`++-- +-*-+ -    **-`	`--`	
Limosa fedoa		`  -      -   - `	`  --  -+----    +  `	`++`	
Hydroprogne caspia		`    ++    ---  `	`     -++-     -`		
Larus philadelphia			` + .++*-  .  --+..`		
Aechmorphorus occidentalis		`      -`	` +- +    ----+   +`		
Podiceps nigricollis		`      -   +`	`-----+ + -`		
Larus canus			`    - +--+++++ -   -`	`-`	
Mergus serrator			`         +-+-`		III
Rissa tridactyla			`           -`		
Sterna hirundo			`        --  -`		
Aphriza virgata		`-`		` +`	
Pandion haliaetus				` -`	
Numenius phaeopus			`   -   +         .`	` +`	
Gavia immer			`   -`		
Melanitta deglandi		`  +      +`		` -`	
Pelecanus occidentalis		`  -    -`			
Arenaria melanocephala		`   +- -`	`           -`	`+*-`	IV
Calidris mauri			`       .`	`+++`	
Limnodromus scolopaceus				`-`	
Actitis macularia			`  -              -`		
Larus argentatus			`       +   +     + `	`  -`	
Calidris alpina				`  -`	
Larus glaucescens			`       -          -`		
Ardea herodias		`            -`	`     -      -`		
Gavia stellata			`            -`		
Charadrius vociferus		`    -        --`	`     +       +`		
Megaceryle alcyon		`             -`	`     -`		
Calidris minutilla		`    -`			V
Corvidae corvus			`             -`		
Phalacrocorax auritus		`    +++     + `	`+  +       --   -`		
Thalasseus elegans		`   - +     - --`	`-+  +`		
Egretta thula		`     -`			

Table 8.3B. Stations X50 and X52 combined.

Year	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	
	4	4	3	4	4	3	3	4	3	3	4	4	3	4	3	3	3	4	3	4	4	3	4	4	4	3	4	3	4	4	4	3	4	4	4	4	4	
Month	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	
	6	7	9	6	7	1	9	9	8	0	8	9	9	9	9	1	8	2	2	3	3	2	5	6	5	0	4	2	6	2	2	2	1	3	3	3	1	
Day	3	2	1	2	1	0	2	2	1	0	2	0	0	0	2	1	1	0	0	2	3	2	0	1	1	2	2	0	0	1	2	2	2	1	0	0	0	
	0	8	4	3	4	3	2	9	0	6	5	8	7	2	9	0	7	2	8	2	0	9	4	6	8	7	0	1	2	6	3	2	6	6	9	2	5	
Aphriza virgata						−																																
Arenaria melanocephala						−																																I
Larus delawarensis						+																												−	+			
Gavia immer	−	−		−	+				−		+	+																										
Gavia stellata	−	+	−	−	+	−	−		+		−		+	+																								
Larus heermanni			−	−	+	+	+	+	+	+	+	−			−	−		−															+	−	+		−	
Sterna forsteri							−	−	−	−	+	+	+																					−				II
Pelecanus occidentalis			−		−		−	−	−		+			+	−								−	−	+													
Aechmorphorus occidentalis						+	−	−	+						−	+	−									−												
Larus occidentalis	−	−	−	−	+	+	+	+			−					+							−	+	+	−	−	−	+	−	−		−	−	+	−	−	
Melanitta perspicillata	−	−			−	−					−	−											−		−	−				−	+	+	−	+	+	+	+	
Catoptrophorus semipalmatus																																				−	+	
Larus canus																															−						−	
Hydroprogne caspia							−			−																											−	
Pluvialis squatarola																										−	−										−	
Larus philadelphia																							+	+											−		−	III
Larus argentatus																																			+	−		
Mergus serrator																				+							−						−	−	−	+		
Rissa tridactyla																									+										−			
Gavia arctica																−	+																−					
Podiceps nigrocollis															+	−																		−			−	
Ardea herodias		−																																				IV
Phalacrocorax pelagicus																												−										
Stercorarius parasitticus											−																											
Thalasseus elegans											−																											V
Larus californicus											+							−																				

Table 8.3C. Station X56.

Year	77777777777777	777777777777	7777777	
	44334444434444	333333333444	4444444	
Month	00110000010000	000111000000	0000000	
	12221233423235	999011889899	6665776	
Day	21200023220210	122001110202	0121123	
	66985220022364	492630077589	2638480	
Calypte anna			-	
Mergus merganser			-	I
Thalasseus elegans		-	+	
Hirundo rustica		-		
Passerculus sandwichensis		-		
Arenaria interpres	--+++--++----	++ +-+----++		
Arenaria melanocephala	+++-+- --+-+ -	+++++--+++-+	- ---	
Catoptrophorus semipalma-	---+++--- --	++-+--- - -+	-	
Pluvialis squatarola *tus*	-+-+++++-++--+	..-+++.. -.+	.-	
Aphriza virgata	+- -++--+-- -	--++-+ -		
Calidris alba	+++++..+-----	-++		II
Heteroscelus incanus	-+-++ - +- ++	+- - -		
Larus philadelphia	-+--+- *+- -	+	-	
Larus argentatus	++- ---+-**-+-	- --	-- -	
Larus glaucescens	-++----- *+-+		-	
Larus canus	--- +- + --			
Melanitta perspicillata	+- . +	+		
Podiceps nigricollis	+- - -	+		
Larus heermanni	.--.-.-...-..	+*+++++-++++	.--.+++	
Pelecanus occidentalis	. -..-.- -	-++-+++--+**	-+.--++	
Larus occidentalis	---------+++--	-+++-+.-+-++	+++++--	III
Rissa tridactyla	.-. -+++---++	- -	------+	
Sterna forsteri	+ +- *	--- -- +-	- +	
Ardea herodias	+ -- +- -	+-++++	'	
Phalacrocorax penicillatus	-	- ++---+		
Aechmorphorus occidentalis	-			
Larus thayeri	-		-	
Dendroica coronata		-		
Mergus serrator	+	+ -		IV
Tyrannis verticalis		-		
Anatidae anas	-			
Numenius phaeopus	-			
Passeriformes parulidae		-		
Phalacrocorax pelagicus	- --			
Wilsonia pusilla	-			
Larus californicus	- - --+	-		
Calidris minutilla	++ --	- +		V
Fulila americana		-		
Larus delawarensis	-- --	-	*	
Phalacrocorax auritus	+ --	--		
Charaorius alexandrinus	-			

Table 8.3D. Stations X58, X59, X60 and X62 combined.

Year	74	74	73	74	74	74	74	73	74	74	73	74	74	74	74	74	73	74	74	74	74	74	73	73	73	73	73	73	73	74	74	
Month	06	06	09	09	06	08	09	11	02	07	09	07	03	03	02	06	12	04	05	05	01	03	08	08	09	10	11	12	12	01	02	
Day	16	23	07	08	30	25	29	03	02	14	22	28	16	22	16	02	22	19	20	08	24	30	10	17	29	06	10	08	22	05	23	
Calidris alba																	-															I
Calidris minutilla																	-															
Catotrophorus semipalmatus																	-															
Heteroscelus incanus																	-															
Pluvialis squatarola																	-															
Arenaria melanocephala																	+							-								
Larus argentatus													+	-			-															II
Larus glaucescens													-	-	-		+															
Larus philadelphia															-	-	+	+	+	-												
Rissa tridactyla	-	-							-	-			+	+	+	-	-	-	+	-	-	+										
Melanitta perspicillata													+			-			+		-											
Larus heermanni	+	-	+	+	+	+	+		-	.	-	-	-		-	.																III
Larus occidentalis	+	-	+	+	-	+	-	+					+	-	-	-	-		+													
Pelecanus occidentalis			-				+									+																
Larus californicus															-	+																
Larus canus															-																	
Phalacrocorax penicillatus																				-												IV
Sterna forsteri						-					+			-					-	+		-										
Larus delawarensis																															-	
Podiceps nigricollis																										-						

Table 8.3E. Station X61.

Year	73	73	73	73	73	74	74	74	74	73	73	73	74	74	74	74	73	74	74	74	74	74	74	74	74	
Month	09	09	10	10	10	09	09	06	07	08	12	12	03	01	02	02	12	01	03	03	03	04	05	06	05	
Day	07	14	06	13	27	02	29	30	14	17	08	29	09	05	02	16	22	19	16	22	30	20	18	02	04	
Branta nigricans																			-							
Charadrius vociferus																			-							
Gavia immer																			-							I
Mergus serrator																			-							
Larus glaucescens											-	+							-							
Calidris alba			-	+							+	-	+	-	+			-	-							
Podiceps nigricollis			+	+							-	-	+	+	-	-	+	-								
Larus philadelphia											-	-	+	-				-	+	+					-	
Aythya affinis												+	+	+	-	+	-	-		+	-					
Melanitta perspicillata				.	-			.	.	.	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	
Pluvialis squatarola				+		+	+			-	+		-	-	+	+	+	+	-	-	-				-	II
Actitis macularia	-	-				+					-	+	-		+	+			+	-	-					
Larus occidentalis	+	+	+	+	+	+	+	-	+	-	+	-	-	-	.	-	.	-	-	+	-	-	-	+	+	
Phalacrocorax auritus	+	+	+	+	+	+		-	.	.	+	+	-	+	-	-	+		-	-	.					
Arenaria interpres		-	+		+	+	-			+	-		+				+		-	-						
Catoptrophorus semipalmatus	-	-	-	-	-	-	-				-	+	+	-			+	+	-	+	-	-				
Larus heermanni	+	-	+	+	.	+	+	+	+	+	.			-		.	.									
Sterna forsteri	+	-	*	-	-	-		-	-	*	.	.		.												
Calidris minutilla	+	+	-			-	-		+	+					-	-										
Pelecanus occidentalis		-	.		-	+	+	+	+	+		.										.				III
Ardea herodias				+	+					+											-					
Heteroscelus incanus		+	-	+	+					-						+									+	
Hydroprogne caspia								+		+	-															
Sterna albifrons								+	-	-													+			
Arenaria melanocephala						+				+					-				-	-		-				
Larus argentatus										*			-		-	-	-	-	-			+				
Calidris mauri						-									+			-				-				IV
Aphriza virgata										+												-				
Larus californicus		-								-	-	+	-									+				
Gavia stellata													-					-								
Limosa fedoa													-													
Larus delawarensis				+								-	-	-												V
Larus canus																		+	-							
Podiceps auritus																		-								
Aechmorphorus occidentalis																									-	
Fulica americana		-																								
Gavia arctica																-										
Larus hyperboreus						-																				
Melanitta deglandi																					-					
Oxyura jamaicensis			-																							VI
Phalacrocorax pelagicus																	-									
Phalacrocorax penicillatus							-																			
Rissa tridactyla																				-						
Podilymbus podiceps														-												VII
Sterna hirundo														-												

Table 8.3F. Stations X70, X71, X72 combined.

Year	74	74	73	74	74	74	74	74	74	74	74	74	73	73	73	
Month	06	07	08	01	03	03	03	04	05	05	03	09	08	12	12	
Day	30	14	10	13	16	22	30	20	04	18	08	29	17	22	29	
Actitis macularia				-												
Anas cyanoptera				-												
Ardea herodias				-												
Arenaria interpres				-												
Calidris alba				-												
Catoptrophorus semipalmatus				-												I
Charadrius vociferus				-												
Larus philadelphia				-												
Larus thayeri				-												
Limnodromus scolopaceus				-												
Pluvialis squatorola				-												
Hydroprogne caspia											-					
Sterna forsteri											-					II
Thalasseus elegans											-					
Falco sparverius			-													III
Larus heermanni	-	+														

Table 8.3G. Station X73.

Year	74	74	73	73	74	74	74	74	74	74	74	74	74	73	73	74	73	73	74	73	73	73	74	74	74	74	74	74	74	
Month	01	02	12	12	02	03	01	03	03	01	03	02	09	09	10	07	08	10	09	08	10	12	04	05	05	06	06	07	09	
Day	05	02	08	22	16	22	19	16	09	26	30	23	02	07	27	14	10	06	08	17	13	29	20	04	18	02	30	28	29	
Larus heermanni														-	-	+	-	+	-			-	-	+	-	+				
Sterna forsteri										-		-	-	-	-		-	*												I
Hydroprogne caspia																	-													
Pelecanus occidentalis																	+	-	+											
Larus philadelphia	+	+	+	*	-	-	-	-	-	+	-	.																		II
Phalacrocorax auritus										-	-																			
Calidris minutilla									-																					III
Larus occidentalis															-															

Table 8.3H. Station X74.

Year	77777 44444	7777 3333	77 33	777777 443343	77777 33443	777 444	
Month	00000 33112	1111 1122	11 00	000001 899990	00000 89869	000 664	
Day	02011 92596	0121 3025	02 67	202221 529223	11020 74437	012 267	
Aythya affinis		-					I
Gavia immer		-					
Aechmorphorus occidentalis		+	--				
Calidris minutilla			+-				
Pluvialis squatarola			-				II
Megaceryle alcyon	-		-				
Melanitta deglandi	-						
Larus californicus	.+--.	*+**	+	... ..	. .	-	
Larus delawarensis	++++-	-+++	--	---			
Podiceps nigricollis	-- ++	+--+	-				
Larus philadelphia	+.	++ -					III
Catoptrophorus semipalmatus	-++	+		-			
Larus canus	+++-+					-	
Podiceps auritus	+ -	+					
Charadrius vociferus	-						
Rissa tridactyla	. *					.	
Larus heermanni	.-..	---.	++	++++++	-----	.	
Larus occidentalis	--+--	+++-	*	++.-++	- .--	--.	
Sterna forsteri		+		++-++	--		
Actitis macularia		-		+-			IV
Phalacrocorax auritus			-	--	+		
Hydroprogne caspia	+		-	+-			
Larus argentatus		+-	*	.-	.	- -	
Larus glaucescens		+-					V
Thalasseus elegans		-		+			
Melanitta perspicillata		-				-+	VI

Table 8.3I. Stations X83, X85 combined.

Year	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	
	3	4	4	4	3	4	4	4	3	3	4	3	3	3	3	4	4	4	4	4	4	3	3	3	3	3	
Month	1	0	0	0	1	0	0	0	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	
	2	6	1	3	2	2	1	3	0	0	4	1	2	1	9	8	6	8	9	6	9	9	9	8	0	9	
Day	0	0	0	2	1	1	1	0	1	2	2	0	2	1	1	0	2	2	0	1	2	0	2	1	0	2	
	8	2	5	2	5	6	9	9	3	7	7	3	2	0	4	4	3	5	2	6	2	7	2	7	6	9	
Aechmorphorus occidentalis													-														
Larus thayeri													-														I
Actitis macularia												-	-														
Larus philadelphia			-									+	+	-													
Larus glaucescens								-					-														
Megaceryle alcyon								-																			II
Podiceps nigricollis							-	-																			
Calidris minutilla										-																	
Oxyura jamaicensis										-																	
Larus heermanni			-	.	-		.	.	-			-			+	+	+	*	+	+	-	-	-	+	+	-	
Larus occidentalis	-	-	-	-	+	+	+	-	+	-	-	-	+	-	-	.	-	+	-	+	+			+	-	.	III
Larus californicus			-	-	+	*		+		-	-	-	+	+			-	.							-	+	
Larus delawarensis			+	+	-		+	+	+	+	-		+	-				-					-				
Larus canus			-	-		-	+																				
Podiceps auritus			-																								
Phalacrocorax auritus														-								-	+	-	+	+	
Sterna forsteri				-														+	-		-	+	-	-	+		
Hydroprogne caspia																								-			
Ardea herodias																										-	IV
Hirundo rustica											-																
Fulica americana																					-						
Thalasseus elegans												-						-			+						
Catoptrophorus semipalmatus									+	-											-				+		
Larus argentatus														+					+	-							V
Rissa tridactyla																				-							

Table 8.3J. Stations X82, X86 combined.

Year	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	
	4	4	3	3	3	3	3	3	4	4	4	4	3	3	4	4	4	3	3	4	3	4	4	
Month	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	1	1	0	1	0	0	
	8	9	9	9	0	8	9	9	8	6	6	6	2	0	3	4	3	1	2	1	2	1	1	
Day	2	0	0	1	0	2	2	2	0	0	2	1	2	1	0	2	2	1	0	0	2	1	2	
	5	2	7	4	6	7	2	9	4	2	3	6	9	3	9	7	2	0	8	5	2	9	6	
Larus californicus	.	.	.	.	-		-	-		-	-			-	-	+	+	+	-	-	*	+	+	
Larus delawarensis	.	-	-	-			.	-						-	-	-	+	+	+	+	+	+	+	
Larus heermanni	+	+	+	+	-	+	-	+	+		+	-	.	+	-		-	-	-	-	-	-	-	I
Larus occidentalis	+	+	+	+	-	+	+	+	.	+	+	+	.	-	-	-	+	+	-	-	+	+	-	
Sterna forsteri	+	-	+	-	+	+	+	-							-	-	-	-						
Larus canus															-					-	+	-	+	
Larus philadelphia																		+	+	-	+	-	-	
Podiceps nigrocollis														-	+	-					-	-	+	II
Catoptrophorus semipalmatus							-														+			
Larus glaucescens																	-				+	-		
Actitis macularia													-											
Ardea herodias								-					-											
Melanitta perspicillata													+				-			-				III
Podiceps auritus																				-				
Hydroprogne caspia						+	-	-	+														-	
Phalacrocorax auritus				+		-	-	+																
Butorides virescens								-																
Pelecanus occidentalis					-			-				-												IV
Megaceryle alcyon	-			+	+																			
Larus argentatus	-	-										+				+					+			
Rissa tridactyla												+											-	
Hirundo rustica											-													

Table 8.3K. Stations X80, X81, X88, and X89 combined.

Year	777777777 333433443	77777 44444	7777 3334	7777 3444	7777 3334	
Month	010000001 909889990	00000 24366	1110 1221	1000 2613	0110 9018	
Day	202211021 962574223	12212 67263	1100 0585	2010 2299	0200 7734	
Phalacrocorax auritus	+++--+++-					
Sterna forsteri	--+ +---				+	
Larus californicus	*+-.	+++ .	.-	.		I
Larus occidentalis	++++--++.	---++	----	.--		
Larus heermanni	++ -	+	.	.		
Larus argentatus	-	-+ --		-		
Larus delawarensis	+-	--	+	+-+-		II
Larus glaucescens		-				
Thalasseus elegans	-					III
Aechmorphorus occidentalis			-			
Carus canus			++ -			
Megaceryle alcyon				-		IV
Podiceps nigricollis			-	+-		
Carus philadelphia			++-	-		

Table 8.3L. Station X84.

Year	7777 4434	7777 3344	7777 3443	
Month	0010 8906	0000 8913	1001 1302	
Day	2012 5233	1122 7462	1011 0995	
Calidris alba			-	
Calidris mauri			-	I
Charadris hiaticula			-	
Larus heermanni	+	+--	+-	
Larus occidentalis	+++-	.-.-	+- +	II
Larus delawarensis			+---	
Catoptrophorus semipalmatus		--		III
Larus californicus		-	+	

Table 8.3M. Station X91.

some regularity in the winter, of which the Willet is most commonly observed. The Willet is the one shorebird species which reaches its near maximum numbers in this area. The Willet feeds and roosts in a variety of habitats within the harbor, many of them in or near areas of fairly heavy human use. It would consequently be the most likely of these shorebird species to adapt to apparently adverse conditions present at this station. This species also occurs at Station 51 in maximum numbers when it is near its peak throughout the harbor. Many of the species which would roost or feed here also occurred in large numbers on the same date, and one can speculate that there was either little human use of the area then or that neighboring areas were more heavily used than was this one.

Group Five contains ten species, seven of which account for a sizable percentage of birds in the area. These birds occur in all four seasons, and five of these species are gulls. The California Gull occurs in maximum numbers here at the beginning of spring migration, although it also occurs in large numbers in the fall and winter. The Mew Gull, on the other hand, is primarily a wintering bird. While a number of species are sighted infrequently in this area, the last seven species listed on the table are the principal avian components of Station X51.

In short, X51 is an area subject to more or less continuous disturbance, particularly on weekends when the survey was conducted. It is populated primarily by gulls on a nearly year-round basis, with Heermann's and Western Gulls predominating. The presence of thirty species indicates the appeal of this area to a number of species, however casual their use might be.

Stations X50 and X52 are at the Sea Scout Base and the main public part of Cabrillo Beach. This area is characterized by sandy beaches and protected water. In addition, both areas receive heavy human use, particularly on weekends, when the survey was most frequently run. In all, 46 species of birds were observed in this area; the large number is attributable to the lack of man-made structures, the presence of natural beach, and diversity of habitat available.

The first species similarity group includes five species, present mainly in fall or winter. One of these five is the Least Tern, and it is important to note their presence in the area.

Group Two contains 15 species, seven of which are of the family Laridae. Most of these occur throughout the

year, with the exceptions of Eared and Western Grebes, Bonaparte's Gull and Caspian Tern. All the second group species occur most commonly from late fall to early spring.

Group Three comprises four species present mainly in winter. The frequency of the Mew Gull in this area, and occurrence of the Common Tern and Black-legged Kittiwake are worthy of note.

Group Four contains 13 species observed casually through the year. Many of these are shorebirds, and they are observed most commonly when they arrive in late summer and early fall and when they depart in early spring. This group also contains the Osprey, which frequented this area of the harbor only.

Group Five contains nine species observed mainly in late summer, fall and winter. Of these, the Double-crested Cormorant and Elegant Tern were most commonly observed.

In summary, Stations X50 and X52 encompass a fairly natural beach area subject to regular, intensive human use. The area is attractive mainly to various gulls and shore-birds. The occasions when the greatest numbers of species and individuals occurred were dates when human use was minimal. The high number of species is due to varied hab-itat, and the most frequent use of the area is from fall to early spring. This is a significant bird area.

Station X56 is the water adjacent to the section of the breakwater running from Cabrillo Beach to Angels Gate Light Station. The area is subject to disturbance from fishermen in boats and on the breakwater, but is relatively well-endowed with birds, 26 species in total.

When the tabular data are examined, a fairly clear pattern emerges. Species Group One contains two shorebird species, mostly seen in flight through the area, and the Ring-billed Gull, whose limited presence indicated that this bird favors other locations. The two shorebird species were seen only on one winter date. The Ring-billed Gull was seen both in the winter and early spring, but on the spring dates it was flying, presumably only passing through the area. It probably occurs here in some numbers during this period, which encompasses its early spring migration.

Group Two is comprised of eight species. Of these, the Western Gull and Surf Scoter were observed in all months, and Heermann's Gull occurred in nearly all months. The

presence of the Surf Scoter throughout the year is somewhat unexpected, but there are several possible explanations. Those birds found in the summer months may be birds which did not return to the breeding grounds, or there may be an overlap between birds beginning their spring migration late and birds which are usually non-nesting but fly north and return very early. The Common Loon shows a marked preference for this area and occurs in large numbers, not only in the fall, which would be expected, but also in mid-July. Those birds seen during July included several first-year birds which would indicate a very early nesting season and a very early southward migration. All loon species seen in this area were feeding. When excluding the Western Gull, Heermann's Gull and the Surf Scoter, the remaining five species show strong seasonality, and are present from mid-summer to late fall, with the Brown Pelican occurring in late spring as well. The nearly complete absence of these species, which are present at least through the winter in other areas, is difficult to explain and would be an interesting point to analyze further.

The third species similarity group contains eight species sighted infrequently and mainly in the late winter and spring. All of these species winter in the harbor but are seen at this station principally during migratory periods. Most are flying, indicating this as one of the less desirable areas for these species.

The fourth group contains four species sighted on scattered dates in the late summer, fall and winter. The heron is undoubtedly only flying through the area; however, the other three species all feed here. All are diving, fish-eating birds and it would be of interest to discover how many of these diving birds become tangled or caught by fishing lines.

The fifth group contains three species seen incidentally in late summer. The jaeger is primarily a pelagic species and was normally found in the harbor only on very windy or stormy days. When found in the harbor it was always feeding.

In summary, Station X56 is an area subject to regular human disturbance, and is populated regularly by fewer than a third of the total number of species observed there. It is, however, one of the major areas of occurrence of the three species of loon and the Western Grebe.

Stations X58, X59, X60 and X62 are on the middle breakwater of outer Los Angeles-Long Beach Harbors, where

41 species were observed, making it one of the most populous stations in terms of species diversity.

In examining the time-similarity plot, three broad groups emerge. The first contains dates from December to early May, with 12 of the 14 dates falling from early December to late March. This period included wintering birds and spring migrants. The second date similarity group contains dates from August through early November. This period includes fall migrants, arriving winter residents, and those birds present year round. The third group of dates covers May through July and includes those birds present in the late spring and summer.

An examination of species-similarity groups gives a good idea of the seasonality of birds on the breakwater and in the adjacent water on the harbor side. Group One contains three species, Anna's Hummingbird, Common Merganser and Elegant Tern, all of which were present in late June. It is of interest that hummingbirds observed on the breakwater were actively looking for and finding insect food. The Elegant Tern is a species which, like the Heermann's Gull, migrates south to its breeding area. The occurrence of this species in March is probably attributable to migrants moving south to the breeding range. Those birds found here in June are undoubtedly birds returning early from the breeding ground. Terns seen were flying rather than feeding or roosting and they are not seen here during their peak periods during the late summer and fall. Those birds found at these stations were probably migrants passing through, indicating that this is not normally a desirable area for this species.

Group Two contains the Barn Swallow and Belding's Savannah Sparrow, an endangered subspecies observed mainly in Salicornia marshes. These birds were present in September, and it might be theorized that the Savannah Sparrows were young birds exploring for possible habitat in the post-breeding dispersal period. Although the Barn Swallow nests in the harbor, it was found at the breakwater only on one date in September, indicating that it was either a migrant, or, like the Savannah Sparrow, was a young bird found in an unlikely area during post-breeding dispersal.

Group Three contains 13 species, including four gulls, four plovers, three other shorebirds, Surf Scoters and Eared Grebes. Of the gulls, all are present mainly in winter and early spring, with Herring Gulls observed in nearly every month. The four plover species are present from late summer through early spring, with Black Turnstones observed in every month. In general, the plover species are present on the breakwater at all times except for their breeding season. The

gull species in this group do not make up a very large percentage of the total number of birds found on the breakwater or even a very large percentage of the total number of the gulls found in this area. Both *L. glaucescens* and *L. argentatus* are usually found here only in very small numbers and are usually roosting. *Larus canus* is even less numerous than the previous two species but when found in this area is almost always feeding or flying rather than roosting. *Larus philadelphia,* like *L. canus* when found in this area, is most likely to be feeding or flying. These four gull species are most concentrated in this area during spring migration. They are generally less common here during the winter months and it is not one of the most preferred areas for them. The shorebird species show a seasonality similar to that of the Plovers, but with the exception of the Willet do not return as early as the plovers. The Eared Grebe and Surf Scoter occur from late fall through early spring, with most observations in late fall or winter.

The fourth species-similarity group contains four species of Laridae, as well as a heron and two members of the order Pelecaniformes, for a total of seven species. Of these, the Heermann's and Western Gulls, Black-legged Kittiwake, Forster's Tern and Brown Pelican occur in nearly every month. Heermann's Gull reaches its peak numbers in the late summer through the fall, the Western Gull is most common through the summer and fall, the Black-legged Kittiwake peaks from late winter through spring, the Forster's Tern is scattered through the year, and the Brown Pelican is most common from summer through the fall. Of these last species all but the tern roost here in large numbers, as well as feeding in the area. The tern, on the other hand, is found primarily to be feeding or flying. The herons and cormorants were found here primarily in the fall.

Group Five comprises eight species observed casually, mainly in the fall and winter. It is interesting to note the appearance of the Yellow-rumped Warbler, Western Kingbird and miscellaneous parulid warblers on the breakwater in the fall. All these birds were actively feeding and represent exploitation of unusual habitat during migration, or possibly in some cases, navigation defects which caused these land birds to migrate out to sea.

Group Six contains eight species observed primarily in late winter and spring. These observations in all probability represent birds congregating prior to migration, or birds present during population peaks. The Double-crested Cormorant, California Gull and Ring-billed Gull are found here during this period but only in fairly small numbers.

They are abundant in other areas of the harbor during the same period, indicating that this is not their most preferred habitat but that it is useful to them during the period of peak competition. The presence of Wilson's Warbler, the most numerous spring migrant land bird, feeding on the breakwater in May, is noteworthy.

In summary, the avifauna of the breakwater, both in terms of abundance and seasonality, is generally quite representative of the harbor as a whole. The large populations of birds and consistent avian use can be attributed to the fact that it provides a roost area of relatively natural form that is almost entirely free of human interference. Since the breakwater is an unnatural structure, but of natural materials, the freedom from human presence must be counted as highly significant. Here, as is the case in the entire harbor, gulls are most common, with the shorebird group second. The breakwater is a roost for gulls and a feeding area for rock-inhabiting shorebirds, and as such, is of great importance.

Station X61 is the Bait Barge anchored about 200 meters off the breakwater, and the surrounding water. This area was surveyed separately from the breakwater because of the presence of human activity that provides a food source for some birds.

The first species-similarity group contains six shorebirds, all of which were sighted on a single date at the end of December, except for *Arenaria melanocephala*, which was also seen on a date in August. These species are not particularly important to the area as all were only in transit.

The second group includes birds present in the winter and spring and contains four members of the family Laridae; Herring, Glaucous-winged and Bonaparte's Gulls and Black-legged Kittiwake. The fifth species in the group is the Surf Scoter. The kittiwake, which is usually uncommon in southern California in the winter and is normally well offshore, was observed on more dates than the others in this group; 14 dates versus 6 for the next most commonly occurring species. More remarkable, the kittiwakes were found into the middle of July. Incursions of kittiwakes occur periodically but are unexplained.

Group Three contains fi·· species concentrated primarily in the summer and fall. The Heermann's and Western Gulls are present almost year round, while the others occur here on scattered dates principally in the summer and fall.

The fourth group contains species, only one of which

(Forster's Tern) was observed on more than one date.

Station X61 is a station which attracts relatively few species, 21 total, only half of which occur here with any regularity or in any numbers. Use of the station is overwhelmingly dominated by gulls. Those gulls are almost all feeding, but like most areas where there is human influence, the use of the area is greatest at those times when the competition for food is greatest. This station seems to be the focal point of the kittiwake congregation. Though somewhat larger numbers of kittiwakes are found on the breakwater at Station 60, almost all of those kittiwakes were roosting directly opposite the bait barge.

Stations X70, X71 and X72 include the U. S. Navy Seaplane Basin and adjacent seawall and open water, and are considered for analysis together because they make up one geographic entity in the harbor. They also comprise the area bordering the Least Tern nesting site and many of the tern sightings occurred in these areas. Of these three stations, the majority of the birds were seen in Station 70 and on the breakwater between 70 and 71.

The first species-similarity group in the tabular data contains five species observed casually in the spring, or winter and spring in the case of the Glaucous-winged Gull. The loon is found in only a few other areas of the harbor, but like the rest of the group except the Glaucous-winged Gull, it is probably a migratory bird.

The second group contains eleven species, of which two, the Western Gull and Surf Scoter, were observed in all months. The other nine species were seen mainly in the fall and winter, with Bonaparte's Gull and Lesser Scaup present in winter through early spring. This is almost the only area in the harbor where scaup are found and is also one of the preferred areas for the scoters. That these diving ducks would find this area so particularly attractive is probably attributable to the relative lack of human disturbance.

The third group contains eight species, including four of the Gull family Laridae, as well as Great Blue Heron, Least Sandpiper, Brown Pelican and Wandering Tattler. These species are present most commonly in late summer and fall, with spotty occurrence through the winter. The Least Tern was observed from May through August and ritual courtship feeding was commonly observed. Immature Least Terns were also observed in this area in the late summer. Least Tern preference for this area is probably explained by several factors: first, because of the area's proximity to the potential nesting

area; second, because it is relatively sheltered and the breakwater is a relatively natural structure for roosting; and finally, because the area is relatively free from human disturbance.

The fourth similarity group contains five species, two gulls, two plovers and one other shorebird, observed mainly from winter through spring. Herring Gulls and Black Turnstones were also numerous in late summer. Most of these species were observed on the breakwater and, in the case of the shorebirds, were almost always feeding.

Groups 5, 6 and 7 comprise 16 species observed infrequently at various times of the year. It is interesting to note that the variety of species in this group brings the species count to a total of 45 for the entire area.

In summary, Stations X70, X71 and X72 have a large avifauna, with gulls and shorebirds predominating. The undisturbed rock breakwater is a good roosting area for gulls and a good feeding area for shorebirds. It is further important to note the presence of grebes, loons and waterfowl in the area over a long period of time. This area was the most important area of Least Tern occurrence during the survey period. The great variety of species found here, when compared with similar stations of large variety elsewhere in the harbor, would indicate the importance of two main factors: first, available relatively natural structures or habitat; and second, and probably more important, the relative freedom from human disturbance.

Station X73, identified throughout the survey as a potential Least Tern nesting site, had no Least Terns present during the whole of the two-year period. However, by June of 1975 this potential was fulfilled with a minimum of ten Least Tern nests found and some 20 additional potentially nesting pairs seen in the vicinity.

Data for X73 are sparse because heavy construction grading work was being done on the site during nearly all the survey period and the landscape was substantially altered during this time. In addition, this area was often heavily used by people with motorcycles and off-road vehicles.

Before the area was developed, it comprised a sandy area with sparse vegetation and several brackish ponds which were used by various species of shorebirds as well as sizable numbers of Forster's Terns and Heermann's Gulls. Other species present are noted in the accompanying table.

Most of the species found used the area in the winter,

the terns and Heermann's Gulls being the exceptions which occurred primarily in the summer and fall. The data available for this area are probably not indicative of general patterns of abundance and seasonality that might have occurred there had the area been left undisturbed.

Relatively few species frequent Station X74. Of the eight species observed, only five were seen on more than one date. The table shows relatively clear seasonality groups for the species groups, with Heermann's Gull, Forster's Tern and Brown Pelican present almost exclusively in the late summer and early fall (July through October). Bonaparte's Gull and Double-crested Cormorant were present principally in the winter and early spring.

There were large numbers of dates on which no birds were present, suggesting that this station is not a preferred habitat. When this observation is coupled with the fact that Heermann's Gull, Forster's Tern and Bonaparte's Gull occur at the sewer outfall only during their population peaks, it suggests that this station may be used only when population pressures dictate feeding in non-preferred areas.

In summary, Station X74, the sewer outfall, gives a good indication of the species that feed on this type of waste discharge and their seasonality. The presence of the three most frequently observed species only during their population peaks indicates possibly that the sewer outfall is not a preferred feeding area. Similarly, the absence of related species during their peaks may be indicative of food acceptance criteria in the most common species that permit them to feed in this area while others do not. Station X74 is an area where feeding behavior dominates, indicating the importance of the site to those species that do feed there.

Stations X80, X81, X88 and X89 comprise the main channel of the Los Angeles Harbor, a relatively narrow waterway bounded by docks and wharves. As would be expected, the avifauna of this area consists almost entirely of gulls, but with important populations of certain other species present, including Forster's Tern, Eared Grebe, Caspian Tern and Double-crested Cormorant.

When the tabular data for the main channel are broken into similarity groups, fairly clear patterns of seasonality appear.

The first species-similarity group, comprised of four Gull species and Forster's Tern, are common through the year, except that Forster's Tern and Ring-billed Gull were

not observed in this area in June. Of the gulls, Heermann's Gull and Western Gull are more common in June to early October, while California Gull and Ring-billed Gull are more common November through January.

The second species-similarity group comprises birds that are observed primarily in November through January, which are some of the representative wintering birds in the harbor.

The third species-group consists of birds also observed primarily from November to January, but in much smaller numbers than the preceding group. During this same period, these species tended to be much more numerous in other parts of the harbor, indicating the main channel is not their preferred wintering habitat.

The fourth group consists of birds that occur in this area mainly in June, August, September and October, and of these species, Caspian Tern, Double-crested Cormorant and Brown Pelican remain present in numbers through the fall and winter, but not in the main channel. This might indicate that birds arriving or passing through in migration will attempt to exploit any area, but will settle into better habitat than the main channel for the winter.

In summary, the main channel is characterized by a year-found population of gulls, with the numbers of individual species waxing and waning with the seasons. It is also used as a fall migration rest stop by certain species, and as a limited wintering area by some wintering species.

Station X82 is the turning basin in the West Basin of the Los Angeles Harbor and X86 is Slip 1, extending northeast from the channel. These two areas show a high correlation in the species and numbers of birds present, and have been considered together for analysis.

The first species-similarity group again contains four species sighted exclusively in the fall and winter. Bonaparte's Gull is the one species which occurs here in any numbers and this is during its peak period throughout the harbor. Apparently, Bonaparte's Gull will make use of almost all the available areas in the harbor of open water for both feeding and roosting during its winter residency. This bird rarely, if ever, uses the docks or buildings as roosting sites, unlike the majority of gull species.

The second and third groups comprise five species observed casually from fall to spring. The Ruddy Duck was

seen in the harbor on only two or three occasions, primarily during migration. The Belted Kingfisher occurs from fall to spring, but its absence from these stations except for one March date suggests a bird in migration rather than one of the winter residents.

The fourth group contains six species, of which five are gulls, and four are seen in nearly every month. In this group Heermann's Gull is more numerous in summer and early fall, Western Gull is relatively common through the year, and the California and Ring-billed Gulls are more common in the fall and winter. Those patterns are all similar to the general seasonality patterns for these species throughout the harbor. Few of the other species are found with any regularity in any numbers, suggesting that the gulls find it easier to adapt their feeding and roosting habits to this human-dominated environment.

The fifth group contains eight species, six of which are seldom observed. Only the Forster's Tern and Double-crested Cormorant occur in numbers and then in the late summer and early fall.

The sixth group contains two species observed occasionally in the fall and late spring. The occurrence of the Black-legged Kittiwake in this interior area of the harbor is probably attributable to migratory movement.

Stations X83 and X85 are the two major arms of the West Basin of the Los Angeles Harbor, and have quite similar avifaunas.

In reviewing the tabular data for these two stations combined, a common pattern emerges. The area is most heavily used from late summer through fall and winter, with distinct species occurring at distinct periods.

In considering the species-similarity groups, the first two groups consist of birds seen infrequently in this area, with observations in October, November and December. These birds might well be migrants that explored this area on arrival and later settled in other wintering locations.

Group Three comprises seven species present, primarily in late fall and winter. Of these seven, California Gull uses the area through most of the year, and Ring-billed Gull appears earlier (in August or September) than the other species.

Group Four contains two species. It is not surprising

that Killdeer do not use the area regularly, since little of it is suitable habitat. It is unusual that kittiwakes should be sighted as often as they were, in that X83 and X85 are well removed from the open ocean where these birds are normally found. Extensive kittiwake incursions occurred during the survey period.

Group Five contains seven species present mainly in late summer and early fall, with Heermann's and Western Gulls present most of the year.

Groups Six and Seven contain three species known from scattered observations. Their occurrence is perhaps due to exploration when migratory groups arrive , or congregation in the spring when they are about to leave.

In summary, Stations X83 and X85 are populated mainly by gulls, with a fairly distinct seasonal grouping, with one group present in the late fall and winter and the other present in late summer and early fall. Both groups contain species present through the year, but these species peak by season with their own groups. The presence of 16 species from families other than Laridae denotes the area is of considerable value to other species as well.

Station X84 is a collection of impounded floating logs adjacent to a lumber yard in the West Basin of the Los Angeles Harbor. Use of this station as a popular roost and resting area is probably due to the fact that this part of the West Basin offers few rest points close to the water and not continually subject to human intrusion. Such rest areas are uncommon in any part of the harbor, and where they do occur they are extensively used.

The first group of five species, including three gulls, use the station through most of the year, with seasonal differences in density observed among the species. The regularity of their occurrence suggests that they prefer X84 as a roost.

The second species similarity group is present with somewhat less regularity and abundance than the first group, most commonly in the winter.

The third group, containing just the Elegant Tern, can be considered birds wandering through the area. X84 is not used to any extent by the larger terns.

The fourth group contains species present in the area in the late fall and winter. Of these, the Western and

Eared Grebes were observed in the water near the logs, and the Belted Kingfishers were observed in the air over X84 or on nearby perches. Bonaparte's Gull and Mew Gull use the logs in the late fall and winter, at the times they are most numerous in the harbor.

In summary, Station X84 is a protected rest area near the water, and is utilized by some species almost continually from August through June, and by others during fall and winter population peaks. The number and diversity of birds using X84 indicate the importance of rest areas close to the water and protected from human intrusion.

Station X91 -- wooden docks in Cerritos Channel -- is a station used by relatively few species over a limited period of the year. Of the species sighted on more than one date, all were gulls except for the Willet. The other three species sighted on one date are shorebirds, and their presence in the middle of December, when the wintering population is high, is not unexpected, even at a relatively inhospitable station such as X91.

The presence of birds at X91 is confined almost entirely to the late summer, fall and winter. The presence of some species in the spring (March) might be indicative of pre-migration restlessness. The large number of summer, fall and winter dates on which no birds were observed indicates that the area is of marginal interest for avian use and may be only a rest point for birds travelling through the harbor. It is possible that the bridges directly west of X91 present a wind barrier for shelter. Willets are commonly seen on rock rip-rap in the interior of the harbor.

BEHAVIORIAL ANALYSIS

The tabular data on avian behavior in the harbor are broken into five categories: UNSPECIFIED, for birds whose behavior was not noted or could not be determined; FEEDING, for birds actively acquiring or searching for food; RESTING, birds at rest; FEED/REST, for species on the water alternately feeding and resting; and FLYING, for birds in transit over a station (see Figure 8.3).

It is important to note that the results presented here indicate behavior at each station by the total number of individuals for all species exhibiting each type of behavior. As a result, behavior percentages derive mainly from the most numerous species, the gulls and shorebirds. While these are very useful data in determining overall use of stations by all species, they do not deal with behavior for individual species at each station. This would require a much more thorough analysis of the observation data and would be interesting to investigate at a later date.

Behavior data are reviewed below in a discussion of each behavior type and the stations where each type of behavior was most frequently observed. Unspecified behavior will not be discussed because it does not represent a discriminated behavior category.

FEEDING

Feeding stations are defined for this brief discussion as stations where 20.00% or more of the birds present are feeding. These are stations 52, 56, 61, 69, 73, 74, and 75.

Sandy beach areas include stations 52 and 75, and are used extensively by both shorebirds and gulls. Station 75 includes the cannery outfalls, and the sandy beach at this station was used very heavily by gulls for feeding.

Open water areas at stations 56 and 69 are used by gulls, grebes, loons and waterfowl. They offer a sheltered, deep water zone bordering a breakwater or embankment.

Human activities provide a food source at areas in-

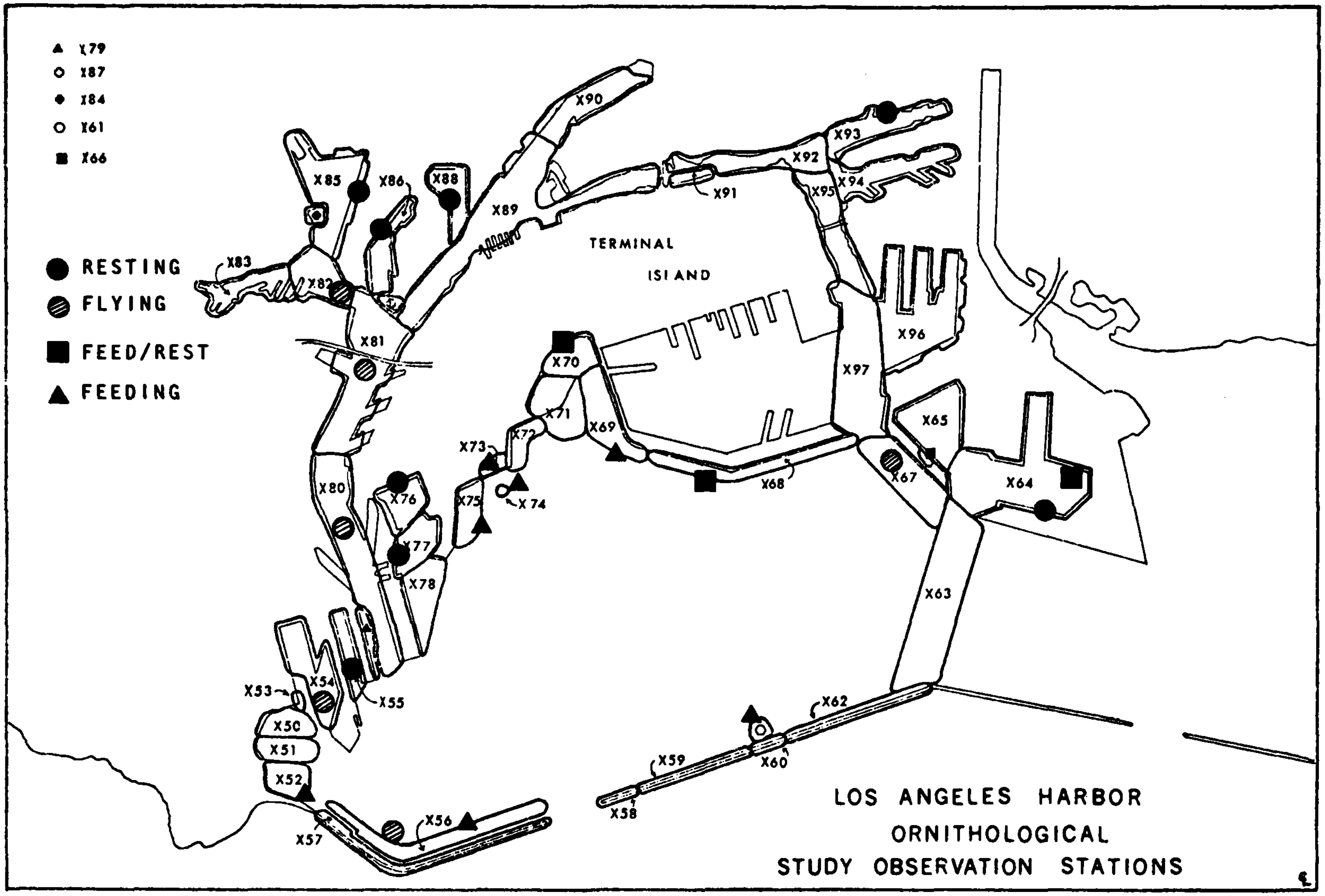


Figure 8.3. AVIAN BEHAVIORAL ANALYSIS

cluding station 61, the bait barge, where numerous gulls, kittiwakes and terns feed. Station 74 is the sewer outfall, used extensively as a food source by Heermann's Gull, Bonaparte's Gull and Forster's Tern.

Station 73, the Least Tern nesting area, was used very heavily by shorebirds presumed to be feeding before development eliminated the brackish ponds there.

RESTING

Resting areas are those station at which 50.00% or more of the birds observed are at rest. Rest stations can be divided into five categories, listed below in descending order of prominence as resting locations.

Tributary, dead-end channels, slips. This class includes nine stations: 55, 64, 76, 77, 85, 86, 88, 93, and 96. These are areas of relatively little daily disturbance, other than ships docking and unloading or being loaded. Nearly all the resting birds in these stations are gulls. These are the backwaters of the harbor, offering little disturbance and providing shelter from rough water and wind.

Breakwaters. This class includes seven stations: 53 (a rocky point), 57 through 60, 62, and 71. These areas are protected from human disturbance and offer convenient rest spots near the water out of the wind. All the breakwaters in the harbor are densely populated with the pelagic gulls, herons, shorebirds and pelicans. Station 71 was used extensively by the Least Tern and Double-crested Cormorant as well. In terms of the average number of birds accommodated, breakwaters are the most important rest areas in the harbor.

Isolated docks, log booms, etc. These varied rest stations, 51, 79, 84 and 87 are grouped because they are all small wooden docks, log booms or small features found within the harbor. Some are used because of their proximity to open water, such as stations 51 and 79. Others are popular rest areas because they offer a good spot close to the water, out of the wind where there are few other suitable locations, particularly at station 84. Others are chosen presumably because they provide a wide field of view and are at the junction of channels, such as station 87. Most birds at these stations are gulls.

Open water. Two stations, 63 and 78, were used heavily as rest areas in open water. These rests are probably used by birds who have recently been feeding in the harbor or at sea, or are about to feed. It is presumed that these are interim stops, used by birds in their daily transit from upchannel roosts to feeding areas and back. Gulls, terns and pelicans use these areas.

Main channels. The main channel stations, 81 and 97, of the Los Angeles and Long Beach Harbors, are important rest areas. The same conditions, are found in certain parts of the main channel as are found in tributary channels and slips are attractive to birds, namely minimal dock activity and dock and warehouse resting areas. In addition, it is the more pelagic species of gulls that use these rest areas, while the coastal members of the family Laridae prefer to be in more quiet inland waters.

FEEDING/RESTING

Stations listed as feed/rest areas are those stations with over 2.00% of the birds present placed in this behavior class. This includes only stations 64, 68 and 70. The most common bird to which this measurement applied was the Surf Scoter, although it was applied to all waterfowl (Anseriformes), loons and grebes. Surf Scoters outnumbered the other species greatly, and stations 64, 68 and 70 are areas of Surf Scoter concentration. Stations 64 and 70 were also significant areas for grebes as well.

FLYING

Areas at which over 10.00% of the birds observed were flying or in transit from one area to another include stations 54, 56, 67, and 80 through 82.

Stations 67 and 80 through 82 can be designated main flyways, since birds must travel through these areas to enter or leave the Los Angeles and Long Beach Harbors and the West Basin of the Los Angeles Harbor. Most of the birds seen flying through these areas were gulls.

Stations 54 and 56 must be considered separately. It is possible that some of the flying activity in both these stations is related to the fact that these stations are near the edge of the harbor. Human disturbance on the breakwater at station 57 causes many birds to fly into station 56, and birds seen flying in 54 might be exploring this marine channel. Most birds seen in 54 and 56 were gulls, and no doubt many of them were in transit into or out of the harbor.

In summary, behavior noted in the harbor does define areas of use and levels of importance within each behavior group. It is also worth noting that each behavior group is dependent on the others, as the birds need all types of habitat - feeding, resting and flying - to be able to survive in the harbor complex.

IMPACT OF PROPOSED DEVELOPMENT IN THE LOS ANGELES HARBOR AREA

Proposed development of the Los Angeles-Long Beach Harbors as shown on the map (p. 1.4) will have several important effects on the biogeography of the area. First, stations 68 through 75 will be eliminated by the development. Second, the amount of open water in the outer harbor will be greatly reduced. Third, the middle breakwater will no longer be separated from human activity by a large buffer of open water. Fourth, new cul-de-sac channels and slips will be created in what is now the outer harbor.

The proposed development will impact the avian population of the harbor in a number of ways.

First, the elimination of station 68 will have a minor effect on most species, since few birds use this area. Station 68 is, however, an important feeding area for Surf Scoters, and this species would be adversely impacted by its loss. Since a sheltered channel will be constructed where 68 is now, it is probable that more gulls will use the area after development than do now when it is fully open and exposed to the west.

The elimination of the seaplane basin and its associated breakwater stations, 69 through 72, will impact a number of species. First, numerous shorebirds use this area for feeding and roosting, and they would be eliminated by the development. Second, the breakwater at station 71 and 72 is one of the few places where cormorants are found in the harbor, and they would suffer by its removal. Third, Brown Pelicans make extensive use of this breakwater, and would be displaced by its removal. Fourth, this breakwater is a major area of occurrence of the California Least Tern, which is not seen on other breakwaters or in other areas except station 73 to any extent. The impact on this endangered subspecies would be severe.

The elimination of station 73 would remove the only Least Tern nesting site in the harbor (nesting birds were observed at station 73 in June, 1975). This would displace the Least Tern from the harbor as a breeding bird, and when coupled with the removal of the breakwater at station 71 and 72, might remove the bird from the harbor entirely, with the possible exception of sparse sightings of individuals wandering through the harbor. A mitigation site for Least Tern nesting should be considered, even though mitigation sites built for these birds do not always serve as adequate nesting areas. There are factors involved in site and nest location selection that are not fully understood, and the possible construction of a mitigation site should not be viewed as a sure and certain solution to the problem of Least Tern displacement.

The elimination of station 74, the sewer outfall, would adversely impact Bonaparte's Gull and Forster's Tern, both of which use this site extensively for feeding. The displacement of these species is compounded by removal of the sandy beach and associated water area at station 75 and the impact the development would have on open water in the harbor and the isolation of the breakwater.

Elimination of station 75, the sandy beach and its associated water area, would adversely affect Bonaparte's Gull and Forster's Tern, both of which feed extensively in this area, and would have a profound effect on the shorebirds in the harbor. Only three stations in the harbor possess sandy beach, and only station 75 is not subject to continual human disruption. The maximum populations of six species occur at sandy beach areas, and the elimination of any of these stations will profoundly affect the birds that frequent them because sandy beaches are such a rarity in the harbor. In particular, the Sanderling is found predominantly at station 75, and its removal would probably bring about the elimination of any sizeable population of Sanderlings in the harbor.

The reduction of open water in the harbor would affect only those few species using open water areas extensively. These are Forster's Tern, Black-legged Kittiwake, Bonaparte's Gull and the four species of the order Pelecaniformes, Brown Pelican, Brandt's, Double-crested and Pelagic Cormorants. It is important to note that Bonaparte's Gull rarely rests on land and that all these species feed extensively and in some cases exclusively in the open water of the outer harbor.

The proximity of human activity to the breakwater might well compromise its value as an isolated resting and feeding area. Of the species using the breakwater, the shorebirds would be most likely to suffer, in that the gulls would readily roost in the new developed area. The impact on shorebirds might be severe, since the breakwater is one of their most important areas of occurrence and receives heavy shorebird use, particularly from the plovers, through most of the year.

The construction of new channels and slips will benefit most species of gulls by providing new resting areas, and it is assumed that these areas will be densely populated with gulls when built. The new channels would not materially benefit many other species, as evidence suggested by the very low density of non-larid species in the upper channels and slips of the harbor during the survey period.

In summary, the proposed development in the harbor would have little impact on gulls, with the exception of Bonaparte's Gull and Black-legged Kittiwake, and would benefit

gulls by providing roost areas for birds that might be displaced from the breakwater.

Bonaparte's Gull and Black-legged Kittiwake would be adversely affected by the elimination of open water, on which these birds are dependent. Further, Bonaparte's Gull would be severely impacted by the removal of the stations 74 and 75, two of its most important feeding areas.

Of the terns, both California Least Tern and Forster's Tern would be adversely impacted. Forster's Tern would suffer from the elimination of station 74 and the reduction of open water in the outer harbor. California Least Tern would be eliminated from the harbor as a breeding bird by removal of its nesting area at station 73 and might be all but eliminated from the harbor entirely by the removal of the breakwater around the seaplane basin. It is recommended that a mitigation site be considered, with the cautions stated earlier in this statement of impact.

The four species of order Pelecaniformes would be adversely impacted by the reduction of open water in the harbor and the removal of the breakwater at the seaplane basin. The proximity of human activity to the middle breakwater in the outer harbor might also affect the resting population of Brown Pelicans.

The shore birds as a group would be adversely affected by the development as well. Stations 71 through 73 are important shorebird feeding and resting areas that would be eliminated. The Sanderling would be greatly reduced or eliminated by development that removed the existing features of these stations. In addition, the close proximity of human activity to the middle breakwater might also reduce shorebird use of the harbor.

It is important to note that impact on the birds can be viewed in several ways. If one wishes to discuss numbers of birds without considering species, it can be said that the development will have only a minimal impact, since most birds in the harbor are gulls, and gulls will in most cases readily adapt to using the facilities that will be provided by the development. If one looks at the possible impact in terms of species, more species will be adversely affected than will not, since tern, shorebird, pelican and cormorant species outnumber the species of gulls. When viewed in terms of the species that will be most severely impacted, Bonaparte's Gull, Least Tern and Sanderling stand out above all, with a potential for the Pelecaniformes to be severely impacted as well.

It must also be noted that in discussing impact, we

have in all cases been discussing whether the avian species can be accommodated in the harbor after the execution of the proposed development. Here the distinction must be drawn as to the true meaning of impact when applied to these various species. Many species will be impacted, but the potential elimination of a species such as Sanderling will probably not have a great impact on the distribution and population of the Sanderling species throughout its range. To avoid the fatal flaw in this statement, it must also be said that wetlands and shoreline conservation should be practiced when possible to insure that today's numerous species will still be so in the future. The only species in the harbor whose very existence would probably be jeopardized to a degree by the development is the California Least Tern, a species that is now endangered primarily because of the loss of suitable nesting sites to a variety of coastal developments.

Appendix 1. Bird Species and Common Names
Los Angeles-Long Beach Harbors Survey

Actitis macularia (Spotted Sandpiper)
Aechmorphorus occidentalis (Western Grebe)
Anas cyanoptera (Cinnamon Teal)
Anas platyrhynchos (Mallard Duck)
Aphriza virgata (Surfbird)
Ardea herodias (Great Blue Heron)
Arenaria interpres (Ruddy Turnstone)
Arenaria melanocephala (Black Turnstone)
Aythya affinis (Lesser Scaup)
Branta nigricans (Black Brant)
Butorides virescens (Green Heron)
Calidris alba (Sanderling)
Calidris alpina (Dunlin)
Calidris mauri (Western Sandpiper)
Calidris minutilla (Least Sandpiper)
Calypte anna (Anna's Hummingbird)
Catoptrophorus semipalmatus (Willet)
Charadrius alexandrinus (Snowy Plover)
Charadrius hiaticula (Semipalmated Plover)
Charadrius vociferus (Killdeer)
Contopus sordidulus (Western Wood Pewee)
Dendroica coronata (Yellow Rumped Warbler or Myrtle Warbler)
Dendroica townsendi (Townsend's Warbler)
Egretta thula (Snowy Egret)
Empidonax difficilis (Western Flycatcher)
Endomychura hypoleuca (Xantus Murrelet)
Falco sparverius (Sparrow Hawk)
Fulica americana (American Coot)
Gavia arctica (Arctic Loon)
Gavia immer (Common Loon)
Gavia stellata (Red Throated Loon)
Haematopus bachmani (Black Oystercatcher)
Heteroscelus incanus (Wandering Tattler)
Hirundo rustica (Barn Swallow)
Hydroprogne caspia (Caspian Tern)
Larus argentatus (Herring Gull)
Larus californicus (California Gull)
Larus canus (Mew Gull)
Larus delawarensis (Ring Billed Gull)
Larus glaucescens (Glaucous Winged Gull)
Larus heermanni (Heermanns Gull)
Larus hyperboreus (Glaucous Gull)
Larus occidentalis (Western Gull)
Larus philadelphia (Bonapartes Gull)
Larus thayeri (Thayers Gull)
Limnodromus scolopaceus (Long Billed Dowitcher)

Appendix 1 (continued)

Limosa fedoa (Marbled Godwit)
Lobipes lobatus (Northern Phalarope)
Megaceryle alcyon (Belted Kingfisher)
Melanitta deglandi (White-winged Scoter)
Melanitta nigra (Common or Black Scoter)
Melanitta perspicillata (Surf Scoter)
Mergus merganser (Common Merganser)
Mergus serrator (Red Breasted Merganser)
Numenius phaeopus (Whimbrel)
Nycticorax nycticorax (Black Crowned Night Heron)
Oxyura jamaicensis (Ruddy Duck)
Pandion haliaetus (Osprey)
Passerculus sandwichensis (Savannah Sparrow Beldingi)
Pelecanus occidentalis (Brown Pelican)
Petrochelidon pyrrhonota (Cliff Swallow)
Phalacrocorax auritus (Double Crested Cormorant)
Phalacrocorax pelagicus (Pelagic Cormorant)
Phalacrocorax penicillatus (Brandts Cormorant)
Pluvialis squatarola (Black Bellied Plover)
Podiceps auritus (Horned Grebe)
Podiceps nigricollis (Eared Grebe)
Podilymbus podiceps (Pied Billed Grebe)
Puffinus griseus (Sooty Shearwater)
Recurvirostra americana (American Avocet)
Rissa tridactyla (Black Legged Kittiwake)
Steganopus tricolor (Wilson's Phalarope)
Stercorarius parasiticus (Parasitic Jaeger)
Stercorarius pomarinus (Pomarine Jaeger)
Sterna albifrons (Least Tern)
Sterna forsteri (Forsters Tern)
Sterna hirundo (Common Tern)
Thalasseus elegans (Elegant Tern)
Tyrannus verticalis (Western Kingbird)
Uria aalge (Common Murre)
Vermivora celata (Orange-crowned Warbler)
Vireo gilvus (Warbling Vireo)
Wilsonia pusilla (Wilsons Warbler)

Chapter 9

MICROBIOLOGICAL INVESTIGATIONS IN LOS ANGELES-LONG BEACH HARBORS

9.1

MICROBIOLOGICAL INVESTIGATIONS IN LOS ANGELES-LONG BEACH HARBORS

INTRODUCTION

The proximity of the outfall for nitrogenous wastes from the Terminal Island primary treatment plant, and two outfalls for the organic wastes from the canneries led Harbor Environmental Projects to question in 1971 as to whether bacterial contamination might persist in this unusual media mixture of nutrients.

Accordingly, monthly monitoring of Total Coliforms, Standard Plate Counts and BOD was begun by D. M. Juge and G. Griest of Immaculate Heart College in July, 1972 at 10 A stations. In March, 1973, Fecal Streptococcus counts were begun, and Fecal Coliform counts were added in May, 1973.

In addition, diffusion dye studies of the outfalls area were carried out in 1972 and 1973 by Juge and Griest (1973) and Foxworthy (1973). The selection of microbial tests was made in accordance with accepted Public Health procedures for determining the quality of water. The following is a summary of the tests utilized in the harbor.

Total Coliforms. The coliform bacteria include a group of enteric bacteria which are ordinarily harmless in the intestinal tract of humans, but may occasionally cause other infections outside the tract. They are more resistant than enteric pathogens and more numerous, so that they are used as presumptive indicators of fecal contamination of water supplies (Scarpino, 1971).

The coliform group has been used to measure or represent possible fecal contamination of water supplies and finished, treated waters, where public health considerations are paramount. However, according to Scarpino (1971), there has been no recognition or understanding given to the habitat of the coliform group. Coliforms are not only present in the feces of warm-blooded animals, but are also in the guts of cold-blooded animals, in soils and on many plants. The presence of any coliforms in drinking water is not acceptable, but the presence in untreated surface waters is another matter. The native habitat or source of the coliforms should be determined before it can be said that the waters constitute a public health hazard. Furthermore, some non-coliforms are able synergistically to produce false-positive tests. Great numbers of non-fecal coliforms can enter waters during heavy rains, often without increasing hazard to human health (Scarpino, 1971). A rise in total coliforms is evident in

Los Angeles-Long Beach Harbors following heavy rainfall, but dry summertime peaks cannot be explained as run-off. Because total coliform tests are easier to carry out, they are sometimes used as a standard for water quality. Fecal coliform and fecal streptococci tests are necessary to confirm the presence of warm-blooded fecal wastes.

Fecal Coliforms are that portion of the Total Coliforms which originate in warm-blooded animal feces, including man. Fecal coliforms indicate recent warm-blooded fecal contamination, whereas Total Coliforms may indicate recent or remote contamination and also organisms of limited sanitary significance. Fecal Coliform criteria have been established for primary and secondary contact recreation. On this basis, the outfalls area of the harbor should not support recreational activities.

Table 9.1. Fecal Coliform Criteria for Recreation Waters

Water usage	Recommended fecal coliforms/100ml
General recreation	Average not to exceed 2000, with a maximum of 4000, except in specified mixing zones adjacent to outfalls
Designated for recreation	Not to exceed log mean of 1000, nor equal or exceed 2000 in more than 10% of the samples
Primary contact recreation	Not to exceed log mean of 200, based on minimum of five samples taken over not more than a 30-day period; nor should 10% of total samples in any 30-day period exceed 400

A study of the survival of *Escherichia coli* in the ocean waters was made by Vind, et al. (1975). A series of cultures were tested after various incubation times, and showed the following:

1) Cultures incubated in test tubes of 3:1 diluted seawater for 2 hours at 35 C and placed in a 1 liter flask of filtered autoclaved seawater showed a drop in count from about 2000 per ml to 300 per ml.

2) Cultures incubated in test tubes of 3:1 diluted seawater for 24 hours at 35 C and placed in a 1 liter

flask of seawater showed counts at 24 hours of 200,000 per ml instead of 2000.

3) In laboratory tests, 10 ml culture samples were placed in 250 ml flasks of filtered seawater or seawater enriched with tryptic soy broth. In filtered seawater alone, counts dropped from 45,000 to 4000 in 26 hours. But in the enriched seawater, counts soared from 35,000 to 25 million in 26 hours.

This study confirms the persistence and growth of coliform bacteria in nutrient enriched seawater, as was originally postulated. This is verified by the extensive sampling carried on in the area of the sewer and cannery outfalls and elsewhere in the harbor.

Fecal Streptococci include species found in significant numbers in warm-blooded animal feces. Some species are of human origin; others are found in slaughterhouse wastes. Because these groups are not well defined and may have other origins than those indicated above, it is difficult to evaluate their presence in harbor waters. Certainly fecal contamination exists, but the extent to which the group persists in seawater, and other possible sources, is not known.

Standard Plate Count. The recent usage of Standard Plate Counts has been optional, according to Scarpino (1971), and may yield useful information on the quality of the water and the significance of the Total Coliform test. The main importance lies in calling attention to sudden increases in bacteria over previous baselines. Standard Plate Count does not determine anaerobes, which may be important in the waste outfall area.

Since many marine bacteria have not yet been identified to species, it is necessary to identify and enumerate them according to differences in morphology, colony formation and metabolic tests. The roles of microbes in the marine environment are undoubtedly as numerous as they are in terrestrial environments. They are essential to the recycling of organics and to the fixation of inorganics in the functioning of the food web. Whether they present health hazards is not known. If bacterial cycling of nutrients did not occur, no food web would be possible. Their presence in the harbor may also constitute a considerable direct food source for filter-feeding benthic and planktonic organisms. Uptake studies are needed to determine the extent of this nutrient pathway.

The map of Mean Standard Plate Count for 1973 and 1974

Figures 9.2 and 9.3) shows considerable variation between the yearly means. Clearly the outfalls area dominates, but the Los Angeles River channel also shows a high mean, especially in 1974; see stations A7 and D2 respectively on Figure 9.1.

Although the total coliforms for 1973 and 1974 do not show a very high mean at the river mouth (Figures 9.4 and 9.5), seasonal counts showed a large increase in January, 1974, when some 9 inches of rain fell in one storm. The Los Angeles River channel has catch basins upstream, which collect debris and detritus. These overflow during heavy rains and subsequent run-off, and probably exert a strong influence on the microbial and phytoplankton populations in the D station area. The BOD patterns (Figures 9.10 and 9.11) also show the influence of the Los Angeles River and the San Gabriel River to the east (D9), but the A7 outfall area is clearly carrying the heaviest load.

Figure 9.1 shows the microbiological stations sampled. Figures 9.2-9.11 are computer maps of microbial parameters.

The following report by D. M. Juge and G. C. Griest represents information gained during the three-year investigation under USC Sea Grant and Corps of Engineers funding.

THE INFLUENCE OF ABIOTIC FACTORS ON THE MICROBIAL ACTIVITY IN THE HARBOR ECOSYSTEM

INTRODUCTION

A three-year investigation of microbial activity, biochemical oxygen demand (BOD), dissolved oxygen (DO), and certain nutrient parameters has provided data which show that predictive correlations do exist in the interactions between the biotic and abiotic constituents of waters in the Los Angeles and Long Beach Harbors. Deviations from the normal marine bacterial flora at different stations appear to reflect the nature of the non-marine or mixed waters being currently introduced into the harbors. Particularly stressed conditions have been observed in those areas of the harbor that are semi-enclosed, where flushing is poor. The data indicate that two of the most significant factors involved in exceeding the oxygen budget of the receiving waters in these areas are the cannery effluent and the frequent heavy bloom and die-off of phytoplankton.

No one variable, with the possible exception of fecal coliforms, can be used to estimate the presence or level of microbial pollution. Standard plate counts (SPC) must be evaluated in terms of water circulation, extreme levels in abiotic parameters and species distribution within a given population. Other factors which must be considered are BOD and DO. The BOD is an expression of the organic load present

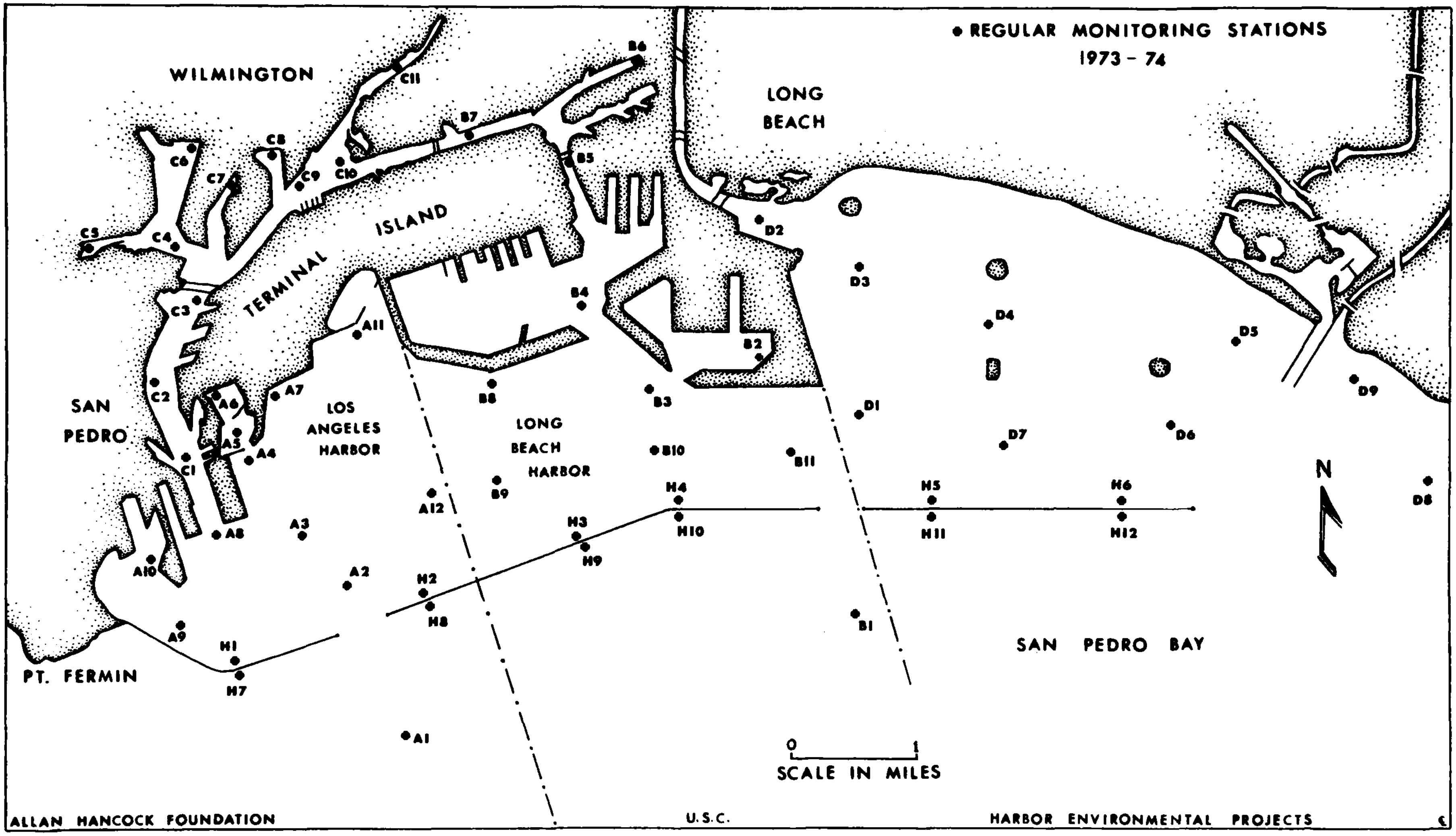


Figure 9.1. Microbiological Sampling Stations.

in the receiving waters. The DO at any given time is an immediate indicator of the turnover of this organic load, water circulation, and oxygenation by phytoplankton. Therefore, the DO is most significant on a day to day basis in most areas and indicates the dynamics of the system.

Some of the difficulties encountered in establishing correlations in data obtained from monthly samples can be anticipated from SPC, DO, and BOD data which resulted from weekly samples taken at station A3 between November, 1973 and June, 1974. These data demonstrate that SPC can have a ten-fold fluctuation in a two-week period.

Instances of human contamination, indicated by a high fecal coliform — fecal streptococcus ratio, periodically occur in certain areas, even though other indices of pollution are not present. In other instances, depending on the time lag between the introduction of the material and sampling, only total coliform,or total coliform and fecal streptococcus, may be found. The infrequency of these occurrences suggests that they may result from ship traffic coupled with a disregard for disposal regulations. Alternately, if total coliforms are demonstrated with any frequency in a given area then an explanation must be sought for both the introduction and persistence of these organisms.

MATERIALS AND METHODS

Water samples for bacteriology were collected in the manner previously described (Juge and Griest, 1973). Samples for DO and BOD determinations are detailed in Juge and Griest, 1975.

Aerobic, Heterotrophic Microorganisms. Standard Plate counts (SPC) were made according to the procedure given in "Standard Methods for Examination of Water and Wastewater" (1971) with the exception that seawater was substituted for distilled water.

The distribution of colony types was obtained by periodically enumerating the different colonies on the isolation plates. Organisms were characterized on the basis of certain physical and biochemical tests. The methods used are described in Juge (1971) and "Manual of Microbiological Methods" (1957), with the exception that in most instances seawater was substituted for distilled water. Litmus milk medium was made with distilled water. The presence and location of flagella were determined by electron microscopy.

Fecal Indicator Organisms. Total coliform counts were made according to the one-stage Millipore (1972) membrane filter technique recommended in "Biological Analysis of Water and Wastewater", using MF-Endo Broth (Difco) as the substrate. Fecal coliform counts followed the same technique but FC Broth Base medium (Difco) was used and the plates were incubated at 44.5°C. Counts for fecal streptococcus used the same filter technique but m-Enterococcus agar (Difco) was used as the substrate.

DO and BOD Procedures. The methods for determining the dissolved oxygen and biochemical oxygen demand for samples were described by Juge and Griest (1975).

Data were stored in a computer bank. Print-outs of data matrices of calculated values for minimum, maximum, mean and standard deviation for each of the 24 parameters were obtained. Computer graphs of the data for each individual station were plotted.

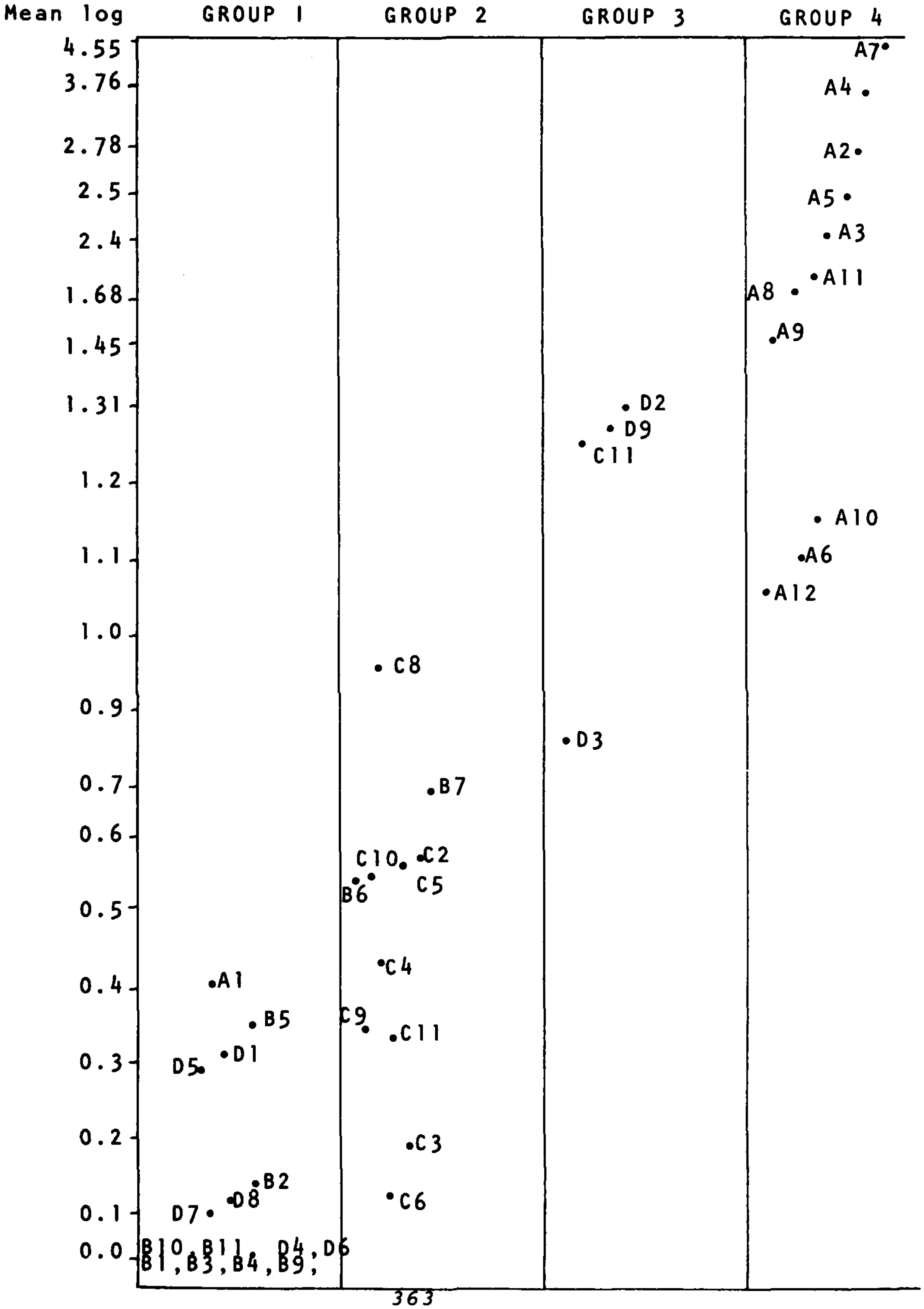
DISCUSSION OF RESULTS

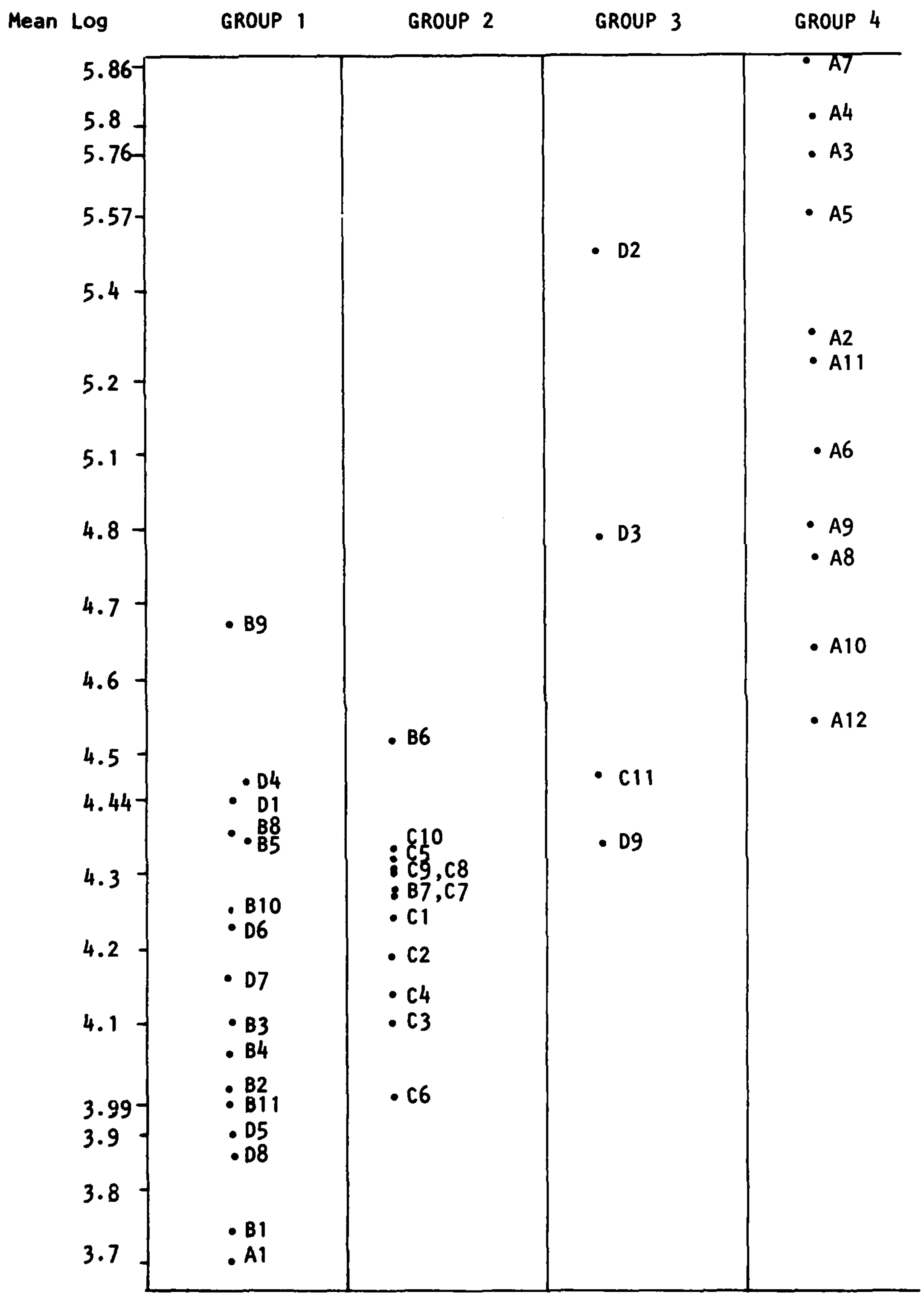
I. Field Studies

Conclusions which will be discussed in this paper were derived from studying the following information: graphs of the data matrices of 24 variables for each individual station, a linear graph of the mean of values for SPC, total coliform, dissolved oxygen, and biochemical oxygen demand (Figures 9.2-9.5; Tables 9.2-9.3). The linear graphs clustered the stations essentially into four groups. In addition, external factors which were considered included: the physical structure of the harbor, circulation patterns, and the type and level of effluents contributed by industry and the surrounding environment.

The first group of stations to be analyzed can be considered as representing a microbial baseline for these waters, although there are intergroup overlappings of the parameters according to the bases on which the stations were clustered. In this category are stations A1 and some of the B and D stations which are not as affected by non-marine sources because they are not near shore and have adequate water circulation. The most significant factor in this grouping is the infrequent and explainable occurrence of coliforms. Second in the order of significance are the level and multiplicity of marine species in the aerobic heterotrophic population present at these stations. The third in the order of significance are the BOD and DO levels.

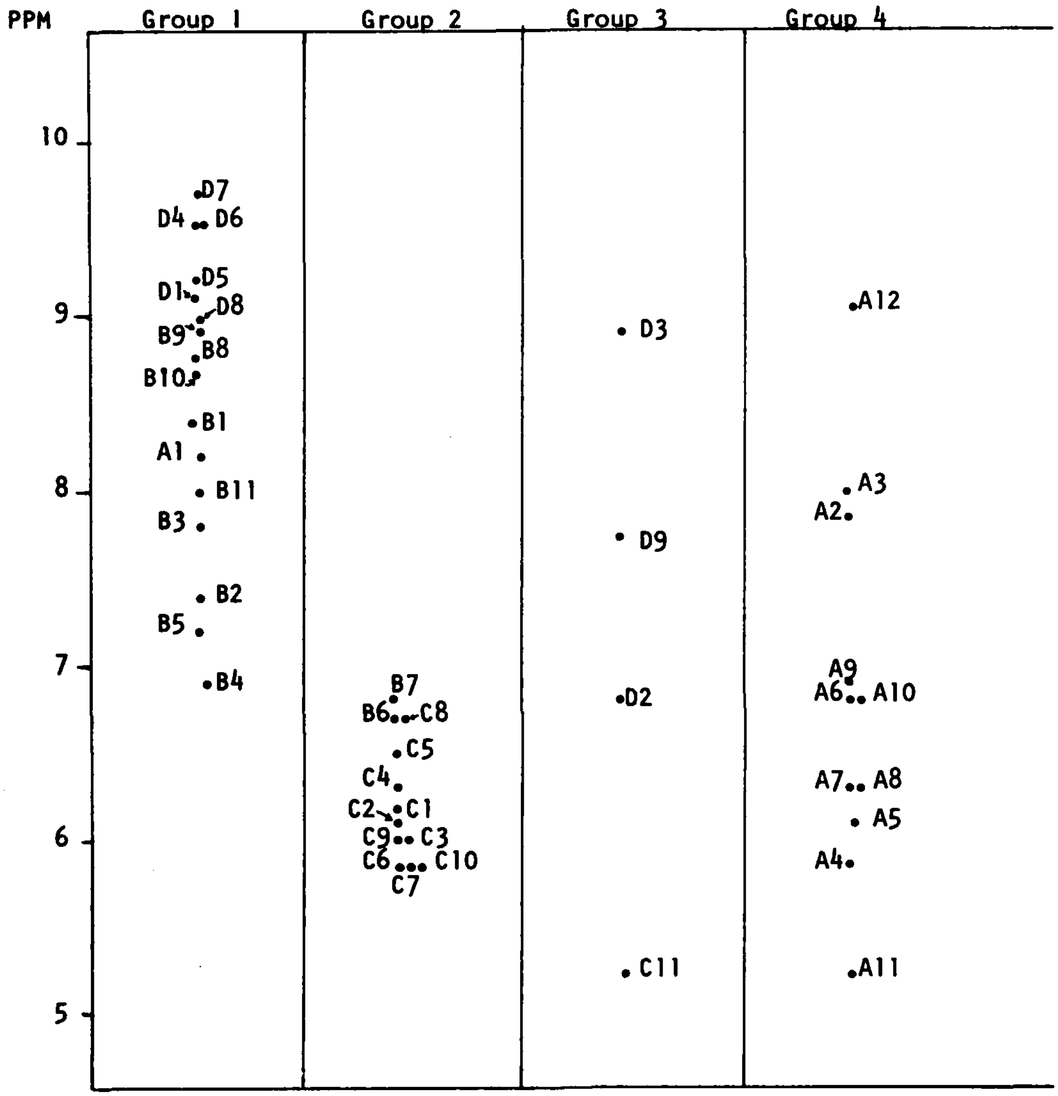
Figure 9.2 . STATION GROUPINGS BY TOTAL COLIFORM, MEAN LOG





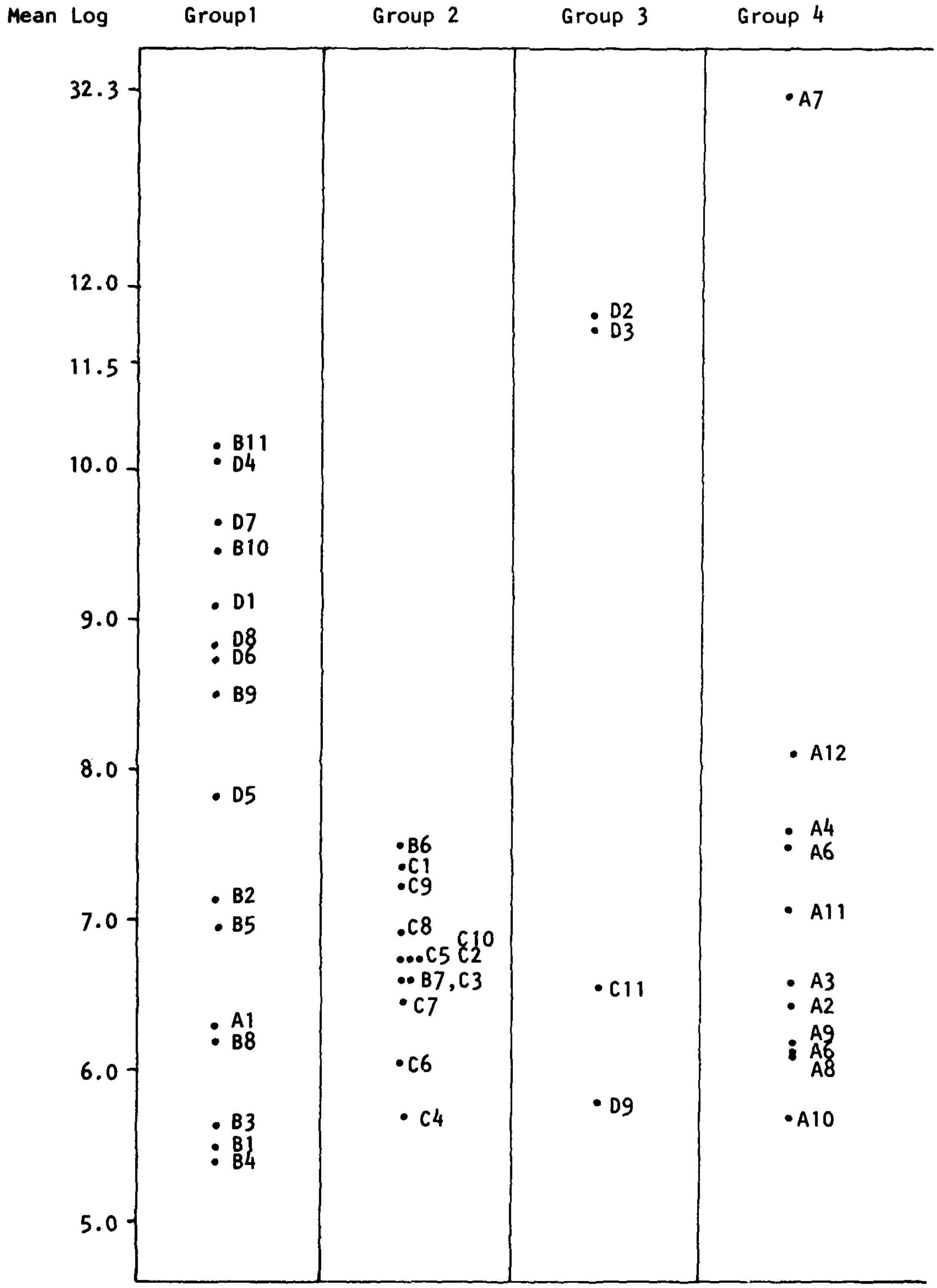
STATION GROUPINGS BY STANDARD PLATE COUNT, MEAN LOG.

Figure 9.3



STATION GROUPINGS BY MEAN DISSOLVED OXYGEN

Figure 9.4



STATION GROUPINGS BY
MEAN BIOCHEMICAL OXYGEN DEMAND

Figure 9.5

Table 9.2. Microbial Data by Station Designation.

Station	Total Coliform (mean log)	Standard Plate Count (mean log)	DO (mg/l)	BOD (mg/l)
A1	0.40	3.70	8.15	6.28
A2	2.78	5.28	7.85	6.44
A3	2.40	5.76	8.00	6.61
A4	3.76	5.81	5.86	7.62
A5	2.50	5.57	6.10	7.52
A6	1.10	5.10	6.82	6.22
A7	4.55	5.86	6.31	32.39
A8	1.69	4.76	6.31	6.09
A9	1.45	4.80	6.90	6.13
A10	1.15	4.64	6.78	5.70
A11	1.70	5.22	5.48	7.09
A12	1.05	4.54	9.04	8.12
B1	0.00	3.74	8.43	5.51
B2	0.14	4.01	7.38	7.13
B3	0.00	4.10	7.83	5.64
B4	0.00	4.06	7.90	5.39
B5	0.35	4.33	7.25	6.97
B6	0.52	4.51	6.72	7.47
B7	0.70	4.28	6.80	6.62
B8	0.00	4.35	8.75	6.21
B9	0.00	4.67	8.91	8.51
B10	0.00	4.25	8.66	9.46
B11	0.00	3.99	8.03	10.16
C1	0.33	4.24	6.18	7.35
C2	0.57	4.17	6.12	6.77
C3	0.19	4.10	5.97	6.59
C4	0.43	4.14	6.3	5.68
C5	0.56	4.32	6.47	6.68
C6	0.15	4.02	5.84	6.06
C7	0.61	4.28	5.85	6.48
C8	0.96	4.31	6.70	6.95
C9	0.34	4.30	6.01	7.24
C10	0.54	4.32	5.82	6.76
C11	1.25	4.47	5.25	6.56
D1	0.31	4.44	9.17	9.11
D2	1.37	5.45	6.83	11.83
D3	0.76	4.79	8.92	11.68
D4	0.00	4.46	9.51	10.06
D5	0.29	3.90	9.20	7.83
D6	0.00	4.23	9.47	8.75
D7	0.10	4.16	9.66	9.64
D8	0.12	3.84	8.99	8.81
D9	1.26	4.33	7.74	5.82

Table 9.3. Microbial Characteristics by Station Groupings.

Group Designation	Mean Log Intervals	Station Number
I	Total Coliform 0.00 - 0.40 Standard Plate Count 3.70 - 4.44 Dissolved Oxygen 7.90 - 9.66 Biochemical Oxygen Demand 5.39 - 10.16	A1,B1,B2,B3,B4,B5,B8,B10 B11,D1,D2,D4,D5,D6,D7,D8.
II	Total Coliform 0.15 - 0.96 Standard Plate Count 4.02 - 4.32 Dissolved Oxygen 5.85 - 6.72 Biochemical Oxygen Demand 5.68 - 7.47	B6,B7,C1,C2,C3,C4,C5,C6 C7,C8,C9,C10.
III	Total Coliform 0.76 - 1.37 Standard Plate Count 4.33 - 5.45 Dissolved Oxygen 5.25 - 8.92 Biochemical Oxygen Demand 5.82 - 11.83	C11,D2,D3,D9.
IV	Total Coliform 1.05 - 4.55 Standard Plate Count 4.45 - 5.86 Dissolved Oxygen 5.48 - 9.04 Biochemical Oxygen Demand 5.70 - 32.39	A2,A3,A4,A5,A6,A7,A8,A9 A10,A11,A12.

Coliforms were never found at stations B1, B3, B4, B8, B10, B11, D4 and D6 (Figs. 9.8, 9.9). Coliforms at stations A1, B2, D1, D5, D7 and D8 are infrequent and can be explained by ship traffic. The nutrient values in these areas fall within the expected range. The SPC levels are low and range from 5.0×10^3 to 5.0×10^4 organisms per ml. It is significant that these plates showed a good distribution of colony types. Averages of DO and BOD readings were slightly lower for the B stations than the D stations. Increased DO at D stations may reflect increased phytoplankton there. In this area, the oil islands provide some protection against dispersion of phytoplankton blooms by prevailing winds. The Los Angeles River is a source of increased BOD; however, water circulation in the harbor east of Pier J is apparently adequate to disperse the organic load, although fish and zooplankton populations are lower than expected at D stations. Station D9 at the San Gabriel River mouth receives warm water from power plants and also storm run-off.

The stations located in the inner channels of the Los Angeles and Long Beach Harbors can be grouped in the following manner: Stations C1, C2, C3, C4 and C6 have some tidal flushing and heavy ship traffic. The low and sporadic levels of coliforms found at these stations can be attributed to the traffic. A few of the occasions of human contamination at station C2 correspond to reported breaks in lines of the sewage system bordering station C2. The SPC level generally remains around 10^4 organisms per ml which is within the previously postulated norm. The distribution of colony types is at an acceptable level; however, the occurrence of chromogenic (indigenous marine) species seems to be less than that which is found at the stations of the previous group.

Coliform levels found at stations C5, C7, C9, C10, B6 and B7 are comparable to that of the C1 group. Station C8 is the exception as it has slightly higher levels of coliforms. SPC levels at these stations are at the upper limits of the presumed norm.

Nitrate and ammonia levels at most of these stations are above the overall mean of these values. Soil run-off, effluents, and inadequate water circulation may be contributing to these high levels. Insufficient water circulation is also reflected in the low levels of dissolved oxygen in channel waters. The mean of BOD values range from 5.6 to 7.4 ppm which indicates a low organic content at these stations. Chen and Lu (1974) identified these areas as well as C11, as the most contaminated with trace and heavy metals and pesticides.

Stations C11, D2 and D3 are greatly influenced by the fresh

water channels feeding into these areas. This is reflected in the salinity values which are the lowest obtained in the harbor. Station C11 is in the area that received heavy loads of pollutants prior to abatement measures instituted in 1970. Station C11 is characterized by stagnant shallow waters whose bottom is stirred by docking vessels. Both coliform and SPC levels are at the upper limit of values found in channel waters. The amount of dissolved oxygen at station C11 is very low, having a mean value of 5.4 ppm. BOD levels are not inordinately high and are comparable to those found at the channel stations located in areas with restricted water circulation. High nitrate and ammonia values can be attributed to detrital run-off.

Fresh water introduced by the Los Angeles River flood control channel affects D2, and to a lesser extent D3. Total coliform and SPC at D2 are high and seem to be associated with this run-off. The slight decrease of population at station D3 may result from mixing with seawater which is evidenced by the salinity level. Soil run-off is probably responsible for the high levels of ammonia and nitrate at these stations. BOD and DO values are high at both stations D2 and D3 which may be due to the frequent occurrence of phytoplankton blooms in this area.

A stations, excluding station A1, are obviously more affected by the activity and effluents from the surrounding areas than are most of the stations previously discussed. Furthermore, because of tidal currents and winds, in particular Santa Ana winds, interactions between the water masses of the stations in this group become an important factor.

The conditions existing at stations A9 and A10 are different from those that prevail at the other A stations. Because they are situated in areas that receive heavy ship traffic or are located adjacent to a beach area, they periodically have significant levels of coliforms. Although the SPC levels are somewhat elevated, the normal marine flora apparently persist. Nitrate levels are high for marine waters and could be attributed to run-off of detrital nitrates. On one occasion a large oiler was observed discharging raw sewage near A10; fuel leaks also occur.

Conditions at stations A2, A3, A4, A5, A8, A11, and to a limited extent A12, range in their intensity of response according to their proximity to station A7. The area of station A7 is considered to be the source of material which is responsible for stressed conditions that affect the marine ecosystem. It is located in the area of both the cannery effluent and the domestic sewage outfall.

At station A7 total coliform counts have been found that exceed 1.0×10^6 organisms per 100 ml. There are two possible sources of this level of coliforms. One is the persistence of the organisms from the raw domestic sewage due to the high level of organic material in this area (Vind, et al., 1975). It should be pointed out, however, that data from dye studies carried out in 1972 and 1973 (Juge and Griest, 1973) indicated that there was a 100-fold drop in the number of coliforms in surface water samples from immediately outside the sewage boil. Counts reversed and began to rise in the area where the water again mixed with the dyed cannery effluent (Figures 9.16-9.18).

The other source of coliforms is that of the system handling cannery effluent itself. In order to determine this, samples were taken (in 1973) from within two of the canneries, at the Way Street pumping station, and in the area immediately adjacent to the combined cannery outfall. Total coliform counts were recorded as high as 3.0×10^8 per 100 ml within one plant and 7.1×10^6 in another. In addition, in the first instance, the fecal coliform-fecal streptococcus ratio was 5, strongly indicating human contamination. In the other instance the counts were as high as 3.5×10^6 and 8.4×10^6 but the ratio was less than one. It is understood that cannery practices have been revised since then; however, no bacteriological data are available to indicate what effects these changes might have had. Data obtained from samples from the Ways Street pumping station and the areas immediately below the cannery outfalls on June 27, 1975 indicate that the coliform levels remain high. The sample taken at the Way Street pumping station contained 3.5×10^7 total coliforms per 100 ml. Although the fecal coliform-fecal streptococcus ratio was not high, there is the assumption (Raymont, 1967) that the survival rate of fecal coliform is less than that of either total coliform or fecal streptococcus in mixed waters. Apparently the total coliforms persist in spite of dilution because the level of total coliform in the waters adjacent to the combined cannery outfall were as high as 6.0×10^6 per 100 ml. The persistence of coliforms in the area of station A7 is a phenomenon that may be attributed to the high organic content of the effluent.

At station A7 standard plate counts are at higher levels than at any other sampling area of the harbor. The range is 5.0×10^4 to 3.0×10^5 organisms per ml. Of particular importance is the narrow distribution of colony types which represents a distinct shift in the aerobic heterotrophic bacterial population. Generally, only five colony types were present as compared to station B1, where, for example, in a count of 35 there were 24 different colony types. Occasionally

during this study coliform counts exceeded the population counts obtained on standard plate count media. This could be expected as coliforms do not grow optimally in seawater media at 18°C. This implies that the presence of coliforms is not a matter of adaptation to the marine environment but represents the continual introduction of organisms.

Nutrient levels also reflect an altered ecosystem at station A7. These levels are far in excess of values found at other monitored stations. This is shown by a striking increase in the level of ammonia. Fluctuations of both nitrate and nitrite values are in accord with this increase. However, their additive value in terms of µg-at N/l is greatly exceeded by the µg-at N/l in ammonia. This suggests that protein nitrogen may be the source, and ammonia is being derived through deamination. The excessively high BOD values that appear to precede the August-September ammonia peaks also seem to support this conclusion. However, BOD values are almost always elevated and are most probably influenced by the level of operation of the canneries. In fact, the BOD values obtained at station A7 are the highest found in the harbor with a mean value of 32 ppm. Although the BOD levels are high, DO values do not drop precipitously because the surface water circulation is sufficient to restore the level of dissolved oxygen.

Stations A2 through A6, A8, A11 and A12 must be discussed in terms of the influence of the material received from A7, as well as their own unique characteristics. Aerial photographs, drogue studies (Soule and Oguri, 1972) and dye dispersion studies (Juge and Griest, 1973) confirm the presence of this material at these stations. The SPC and coliform levels are at the upper limits of the values obtained from all stations monitored in the harbor. However, in accordance with the dispersion and dilution of the effluent material, the values vary with the distance from the outfall. Chamberlain (1973, 1974, 1975), Stephens et al. (1973, 1974) and others have pointed out the rich fish and benthic fauna supported by the high level of nutrients in these areas.

Located at the entrance to Fish Harbor, A4 is the station which, with the exception of A7, is most intensely influenced by the cannery effluent. Total coliform counts are consistently high, having a mean value of 8.0×10^3 organisms per 100 ml. On at least six occasions (October 1973, February, March, June, August, September and November 1974) the fecal coliform-fecal streptococcus ratio was above 2, which suggests human contamination. This may be attributed to the heavy pleasure craft and ship traffic traversing this area. SPC

values are almost as high as those found at station A7 and again the distribution of colony type is narrow. The amount of dissolved oxygen in these waters is lower than average, with a mean value of 5.8 ppm but the BOD values are not inordinately high.

Station A5 is located in outer Fish Harbor, where a marina is situated. Levels of total coliforms are predominantly high, although not as high as that of A4, and occasions of human contamination are less prevalent. As a result, it is difficult to attribute the presence of total coliforms in this area only to ship traffic or the marina. Their persistence may be caused by the presence of effluent material at this station. SPC levels range between 1.0×10^5 and 1.0×10^7 organisms per ml, and the distribution of colony types is narrow. Nitrate values exceed average values for the harbor and ammonia levels are generally lower than those found at station A4.

Station A6 is within inner Fish Harbor where water circulation is low and the effluent material is not usually evident. For this group of stations total coliform counts at A6 are not high. In addition, fecal coliform-fecal streptococcus ratios indicating human contamination were not observed. SPC levels range between 5.0×10^4 and 1.0×10^5 and the plates exhibited a narrow distribution of colony types. Nutrient values are slightly lower than those found at station A5.

In general, the proximity of stations A4, A5 and A6 to one another is evident in the close correlations of biotic data that can be made. The water circulation in the area is poor, with minimal tidal flush.

Station A3 has fairly high coliform levels, although it is in the shipping lane and closer to the breakwater. The SPC is comparable to station A4, although colony types occurring on A3 plates exhibit a slightly wider distribution. The DO, BOD, and nutrient values are not extraordinary here.

Stations A2, A8, A11 and A12 maintain values at the lower limit of this grouping. Persistently high coliform levels are not evident at these stations. Nevertheless, coliforms occur more frequently than might be attributed to ship traffic, but this is the anchorage for ships waiting for docking and was occupied by many large vessels during shipping strikes. The mean range of SPC levels is 5.0×10^4 to 2.0×10^5 organisms per ml. Nutrient values are not inordinately high. Station A8 has a higher than average nitrate value from unknown sources. Reservation Point contains a prison and Coast Guard

facilities, and a large shipyard is nearby.

Although the Los Angeles and Long Beach Harbors are adjacent to a very large metropolitan area its waters are surprisingly clean.

The Characterization of Isolated Marine Microorganisms

Of the 162 organisms isolated during the past two years 17 have stabilized sufficiently to be partially characterized. Table 9.4 lists the samples and the station from which each was collected. Tables 9.5 and 9.6 list the results of the observations and tests carried out to date on these organisms.

All of these organisms are Gram-negative rods or pleomorphic forms, which dominate the bacterial flora of marine environments. However, only eight are motile, which is atypical of marine microorganisms, according to Wood (1965).

Colony morphology on seawater-agar medium showed no consistent characteristics except for the absence of diffusible pigments in 15 of the 17 isolates.

Growth in seawater broth medium occurred in all, as was expected, since they were isolated from the marine environment. In distilled water broth only five of the organisms showed growth. Of the five organisms, one each came from stations C4, C10 and C11, and two from D6. They are possibly of terrigenous or freshwater origin, since the location of the C stations makes such a suggested origin possible. The location of D6, however, suggests that the growth noted in distilled water broth in both samples collected there, represents a broad tolerance of the organisms for differing salinities.

All 17 of these organisms showed growth at 22°C and none grew at 45°C. Three of them showed no growth at any of the other incubator temperatures tested. Six of the organisms showed growth at 8°C and eleven also grew at 37°C. The bacterial flora tested, with few exceptions, is apparently tolerant of a fairly broad temperature range.

Extracellular enzymes were present in tests with all organisms except with organism number 1, although only nine showed the presence of all extracellular enzymes tested for.

The biochemical tests show 11 of the test organisms capable of reducing nitrate, suggesting that they are facultative anaerobes. However, only one showed hydrogen sulfide

TABLE 9.4. Identification Notation of Isolated Organisms

Organism Number	Source of Sample	Notation Number
1	A1	A1-2/1
2	A2	A2-2/2
3	A10	A10-2/1/1
4	A10	A10-2/1/2
5	B5	B5-1/2/1
6	B5	B5-1/3
7	B6	B6-1/2
8	C4	C4-12/1
9	C7	C7-12/3
10	C10	C10-12/1
11	C10	C10-12/4
12	C11	C11-12/2
13	D1	D1-3/1/3
14	D1	D1-3/4
15	D3	D3-2/1
16	D6	D6-3/2/1
17	D6	D6-3/2/3

TABLE 9.5. List and Notation of Physical and Biochemical Tests

Vegetative Cells

Gram Reaction
- 1 - negative
- 2 - positive

Form
- 1 - cocci
- 2 - rods
- 3 - coccobacilli
- 4 - pleomorphic
- 5 - pleomorphic rods

Length (μ)
- 1 - 0.8 to 1.7
- 2 - 1.3 to 1.7
- 3 - 1.7 to 2.6
- 4 - 2.1 to 3.1

Width (μ)
- 1 - 0.4 to 0.7
- 2 - 0.6 to 0.8
- 3 - 0.8 to 1.0

Motility
- 1 - negative
- 2 - positive

Flagella
- 1 - absent
- 2 - unipolar
- 3 - bipolar
- 4 - peritrichous

Sea Water Agar Colony Morphology

Colony size
- 1 - 1mm
- 2 - 1.1 to 2.0mm
- 3 - 2.1 to 3.0mm
- 4 - 3.1 to 4.0mm

Optical characteristics
- 1 - opaque
- 2 - transparent
- 3 - translucent
- 4 - opaque center, translucent edge

Pigment non-diffusible
- 1 - cream
- 2 - beige
- 3 - brown
- 4 - orange
- 5 - yellow
- 6 - red

Pigment diffusible
- 1 - negative
- 2 - positive

Surface
- 1 - smooth
- 2 - rough
- 3 - granular
- 4 - concentrically ringed
- 5 - radially ringed
- 6 - mucoid

Form
- 1 - punctiform
- 2 - circular
- 3 - amoeboid
- 4 - rhizoid

Elevation
- 1 - flat
- 2 - raised
- 3 - convex
- 4 - umbilicate
- 5 - umbonate

Edge
- 1 - entire
- 2 - undulate
- 3 - ciliate
- 4 - beveled

Broth -- Sea Water

Growth
- 1 - negative
- 2 - positive

Surface
- 1 - none
- 2 - pellicle
- 3 - ring

Clouding
- 1 - none
- 2 - slight
- 3 - heavy

Sediment
- 1 - none
- 2 - slight
- 3 - moderate
- 4 - heavy

Growth temperature
- 1 - 8°C
- 2 - 22°C
- 3 - 37°C
- 4 - 45°C
- 5 - 8,22°C
- 6 - 8,22,37°C
- 7 - 22,37°C

TABLE 9.5. (continued)

Broth -- Distilled water
1 - negative
2 - positive

Extracellular Enzymes
Gelatin stab
1 - negative
2 - positive
3 - no growth
Starch hydrolysis
1 - negative
2 - positive
Casein hydrolysis
1 - negative
2 - positive
Tween 80
1 - negative
2 - positive

Biochemical Tests
Litmus milk
1 - no change
2 - reduced-acid
3 - reduced-alkaline
4 - alkaline-coagulated peptonized
5 - reduced-alkaline-coagulated-peptonized
Nitrate reduction
1 - negative
2 - positive
3 - no growth
Peptone -- Ammonia
1 - negative
2 - positive
3 - no growth

Methyl Red-Voges Proskauer
1 - negative
2 - MR pos./VP negative
3 - MR neg./VP positive
4 - no growth
Indole
1 - negative
2 - positive
3 - no growth
Lead acetate
1 - H_2S negative
2 - H_2S positive
3 - no growth
Koser's citrate
1 - no growth
2 - growth
Oxidase Reaction
1 - negative
2 - positive
Catalase Reaction
1 - negative
2 - positive
Hugh-Leifson's Medium (OF)
OF Glucose
1 - oxidative
2 - fermentative
3 - oxidative and fermentative
4 - not utilized
Fermentative Reaction
1 - growth-no reaction
2 - acid-no gas
3 - acid-gas
4 - no growth

TABLE 9.6. Physical and Biochemical Characteristics of Isolated Organisms

Character	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Vegetative Cells																	
Gram reaction	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Form	3	2	5	5	2	5	2	2	2	2	2	5	5	5	3	2	2
Length (μ)	1	3	3	3	2	2	3	1	2	1	2	1	1	3	1	2	3
Width (μ)	1	1	3	2	2	1	2	1	2	1	2	1	1	1	1	1	1
Motility	1	2	1	1	2	2	2	1	1	1	1	2	1	2	2	1	2
Flagella	1	2	1	1	2	3	2	1	1	1	1	*	1	2	2	1	3
Sea Water Agar Colony Morphology																	
Colony size	1	3	3	4	2	4	2	1	2	1	4	1	2	1	1	2	3
Optical characteristics	1	4	3	1	4	1	3	1	3	1	1	3	3	2	4	1	3
Pigment non-diffusible	2	1	2	2	2	4	4	5	3	6	4	5	1	2	3	1	5
Pigment diffusible	1	1	1	1	1	2	2	1	1	1	1	1	1	1	1	1	1
Surface	1	1	1	6	2	4	1	1	1	1	1	2	5	1	1	5	3
Form	1	2	2	2	2	2	2	1	3	1	2	1	2	1	1	2	3
Elevation	3	3	4	3	5	4	3	5	5	3	3	1	2	2	3	3	2
Edge	1	2	4	2	5	1	1	1	2	1	1	1	2	1	1	2	4
Broth--Sea Water																	
Growth	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Surface	3	2	1	3	2	2	2	1	3	1	2	1	3	3	1	2	1
Clouding	3	4	2	3	3	4	4	2	4	2	4	3	4	4	3	3	4
Sediment	1	1	2	2	3	4	1	1	2	2	1	1	3	3	1	1	4
Growth temperature	7	5	6	6	2	7	7	2	2	7	5	7	5	7	6	7	7
Broth--Distilled water	1	1	1	1	1	1	1	2	1	2	1	2	1	1	1	2	2
Extracellular Enzymes																	
Geletin	3	2	2	2	3	2	2	2	2	2	2	2	2	2	3	2	3
Starch	1	2	2	2	2	2	2	2	2	1	1	1	2	2	1	2	2
Casein	1	2	2	2	2	2	2	2	2	1	1	1	2	2	1	1	1
Tween 80	1	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2

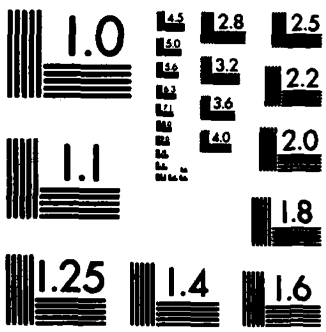
TABLE 9.6 (continued. Physical and Biochemical Characteristics of Isolated Organisms

Character	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Biochemical Tests																	
Litmus milk	1	5	1	1	5	5	4	3	1	3	5	5	1	5	1	5	5
Nitrate reduction	2	1	2	2	1	1	2	2	2	1	1	2	2	2	1	2	2
Peptone	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	1	2
MR-VP	4	1	4	4	1	1	1	1	1	1	1	1	1	1	1	1	1
Indole	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lead acetate	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1
Koser's citrate	1	1	2	2	1	1	1	2	1	2	2	1	2	1	1	2	2
Oxidase reaction	2	2	2	2	1	2	2	1	2	1	2	1	2	2	1	2	2
Catalase reaction	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2
OF-glucose	2	3	4	2	3	2	3	4	2	2	3	2	3	2	2	3	3
Fermentation Reactions																	
Glucose	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lactose	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Maltose	1	1	2	2	1	1	1	1	1	1	1	1	1	2	1	1	1
Sucrose	1	1	2	2	1	1	1	1	1	1	2	1	2	2	1	1	1
Xylose	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1
Glycerol	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mannitol	1	1	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
Salicin	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

* not determined

AD-A136 653 ENVIRONMENTAL INVESTIGATIONS AND ANALYSES FOR LOS ANGELES-LONG BEACH HARB..(U) UNIVERSITY OF SOUTHERN CALIFORNIA LOS ANGELES ALLAN HANCOCK F.. DEC 76 5/8

UNCLASSIFIED DACW09-73-C-0112 F/G 8/10 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

production in the lead acetate test. The reactions noted in the indole, methyl red, Voges Proskauer, and citrate tests, which constitute the IMViC series, as well as the failure to produce gas in lactose broth, rule out the *Escherichia* and *Enterobacter*.

All of the organisms were capable of growth in the media used for testing fermentation reactions. No gas was produced in any of these tests but six of the organisms showed acid formation in some of the media used.

Results of these tests have been compared with the 60 marine organisms isolated and described by ZoBell and Upham (1944) and with a scheme for identification proposed by Bonde (1966). The eighth edition of Buchanan and Gibbons (1974) has also been checked in an attempt to identify these organisms. It would be pointless to establish new names at this time for these organisms. An additional 50 to 60 tests would be necessary in order to perform numerical taxonomy and computer analysis.

LITERATURE CITED

American Public Health Association, Inc. 1971. Standard methods for examination of water and wastewater. 13th edition.

Bonde, G. J. 1966. Heterotrophic bacteria in a polluted marine environment. Third International Conference on Water Pollution Research. Section 3. Paper number 5. pp. 1-13.

Buchanan, R. E., and N. E. Gibbons (eds.). 1974. Bergey's manual of determinative bacteriology. 8th edition. The Williams and Wilkins Co. Baltimore, Maryland. 1246 pp.

Chamberlain, D. W. 1973. Results of fourteen benthic trawls conducted in the outer Los Angeles-Long Beach Harbors, California. May 24, 1972. In Marine Studies of San Pedro Bay, California. Part 2. Allan Hancock Foundation and Sea Grant Program, University of Southern California. pp. 107-146.

Chamberlain, D. W. 1974. A checklist of fishes from Los Angeles-Long Beach Harbors. In Marine Studies of San Pedro Bay, California. Part 4. Allan Hancock Foundation and Sea Grant Program, University of Southern California. pp. 43-78.

Chamberlain, D. W. 1975. The role of fish cannery waste in the ecosystem. In Marine Studies of San Pedro Bay, California. Part 8. Allan Hancock Foundation and Sea Grant Program, University of Southern California. pp. 1-22.

Chen, K. Y., and J. C. S. Lu. Sediment composition in Los Angeles-Long Beach Harbors and San Pedro Basin. In Marine Studies of San Pedro Bay, California. Part 7. Allan Hancock Foundation and Sea Grant Program, University of Southern California. pp. 1-177.

Foxworthy, J. E. 1973. Working paper on the dilution of cannery wastes discharges into the Los Angeles Harbor. In Marine Studies of San Pedro Bay, California. Part 2. Allan Hancock Foundation and Sea Grant Program, University of Southern California. pp. 65-78.

Juge, D. M. 1971. Marine geomicrobiology of the southern California continental borderland. Unpublished doctoral dissertation. University of Southern California. 223 pp.

Juge, D. M., and G . C. Griest. 1973. The roles of microbial activity in the harbor ecosystem. In Marine Studies of San Pedro Bay, California. Part 2. Allan Hancock Foundation and Sea Grant Program, University of Southern California. pp. 30-54.

Juge, D. M., and G. C. Griest. 1975. A modification of BOD method for use in the marine environment. In Marine Studies of San Pedro Bay, California. Part 8. Allan Hancock Foundation and Sea Grant Program, University of Southern California. pp. 46-55.

Manual of microbiological methods. 1957. Ed. by Committee on Bacteriological Technic, American Society for Microbiology. McGraw Hill Book Co., Inc. New York.

Millipore Corporation. 1972. Biological analysis of water and wastewater. Millipore Application Manual A M 302.

Oguri, M., D.Soule, D.M.Juge, and B.C.Abbott. 1975. Red tides in the Los Angeles-Long Beach Harbors. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 8. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 109-119.

Raymont, J. E. 1967. Plankton and productivity in the oceans. Pergamon Press. Long Island City, New York. 468 p.

Scarpino, P.V. 1971. Bacterial and viral analysis of water and waste water. In Water and Water Pollution Handbook. Vol. 2. L. L. Ciaccio (ed.) Marcel Dekker, Inc. New York 800 p.

Soule, D. F., and M. Oguri. 1972. Circulation patterns in Los Angeles-Long Beach Harbor. Drogue study atlas and data report. Marine Studies of San Pedro Bay, California. Part 1. Allan Hancock Foundation and Sea Grant Program, University of Southern California. 113 p.

Stephens, J. S., D. Gardiner, and C. Terry. 1973. The demersal fish population of San Pedro Bay. In Marine Studies of San Pedro Bay, California. Part I. Allan Hancock Foundation and Sea Grant Program, University of Southern California. pp. 147-166.

Stephens, J. S., C. Terry, S. Subber, and M. J. Allen. 1974. Abundance, distribution, seasonality, and productivity of fish populations in Los Angeles Harbor, 1972-1973. In Marine Studies of San Pedro Bay, California. Part 4. Allan Hancock Foundation and Sea Grant Program, University of Southern California. pp. 1-42.

Vind, H. P., J. S. Muraoka, and C. W. Mathews. 1975. The survival of sewage bacteria at various ocean depths. U. S. Navy Civil Eng. Lab. Pt. Hueneme. Tech. Note N-1396. 19 p.

Wood, E. J. F. 1965. Marine microbial ecology. Reinhold Publ. 243 p.

Standard Plate Count, 1973

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	3.53	3.76	3.98	4.21	4.44	4.66	4.89	5.11	5.34	5.57
MAXIMUM	3.76	3.98	4.21	4.44	4.66	4.89	5.11	5.34	5.57	5.79

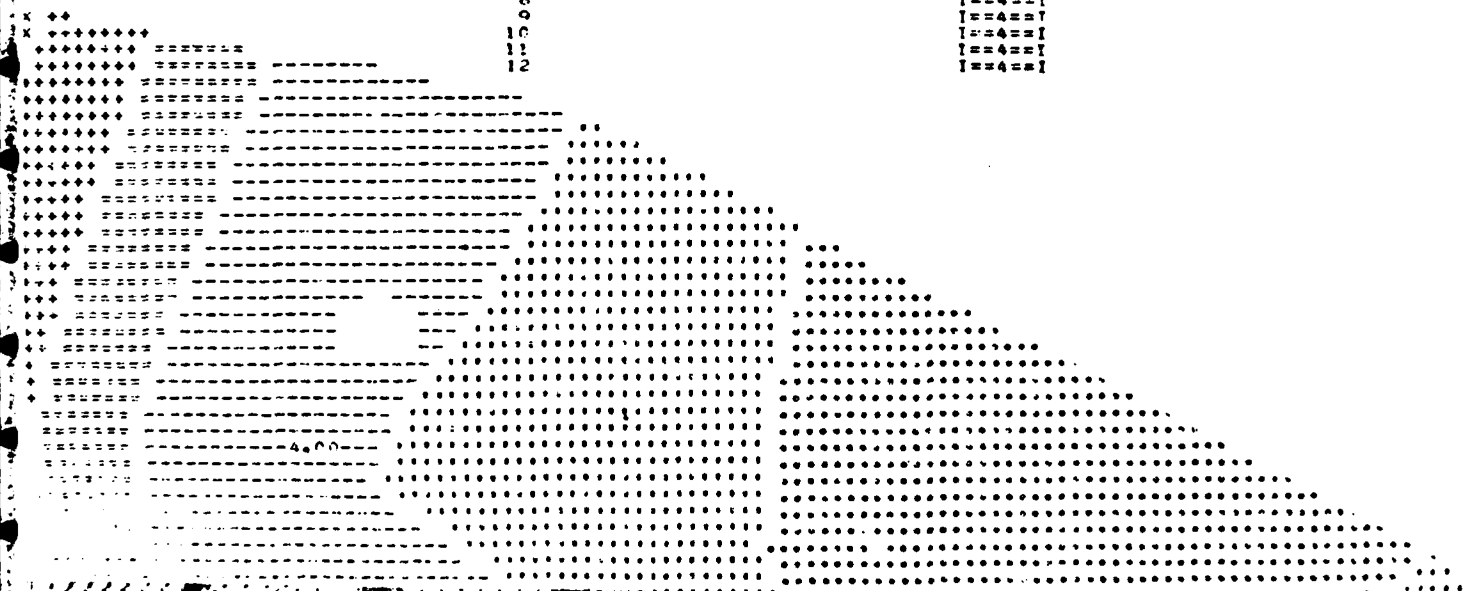
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

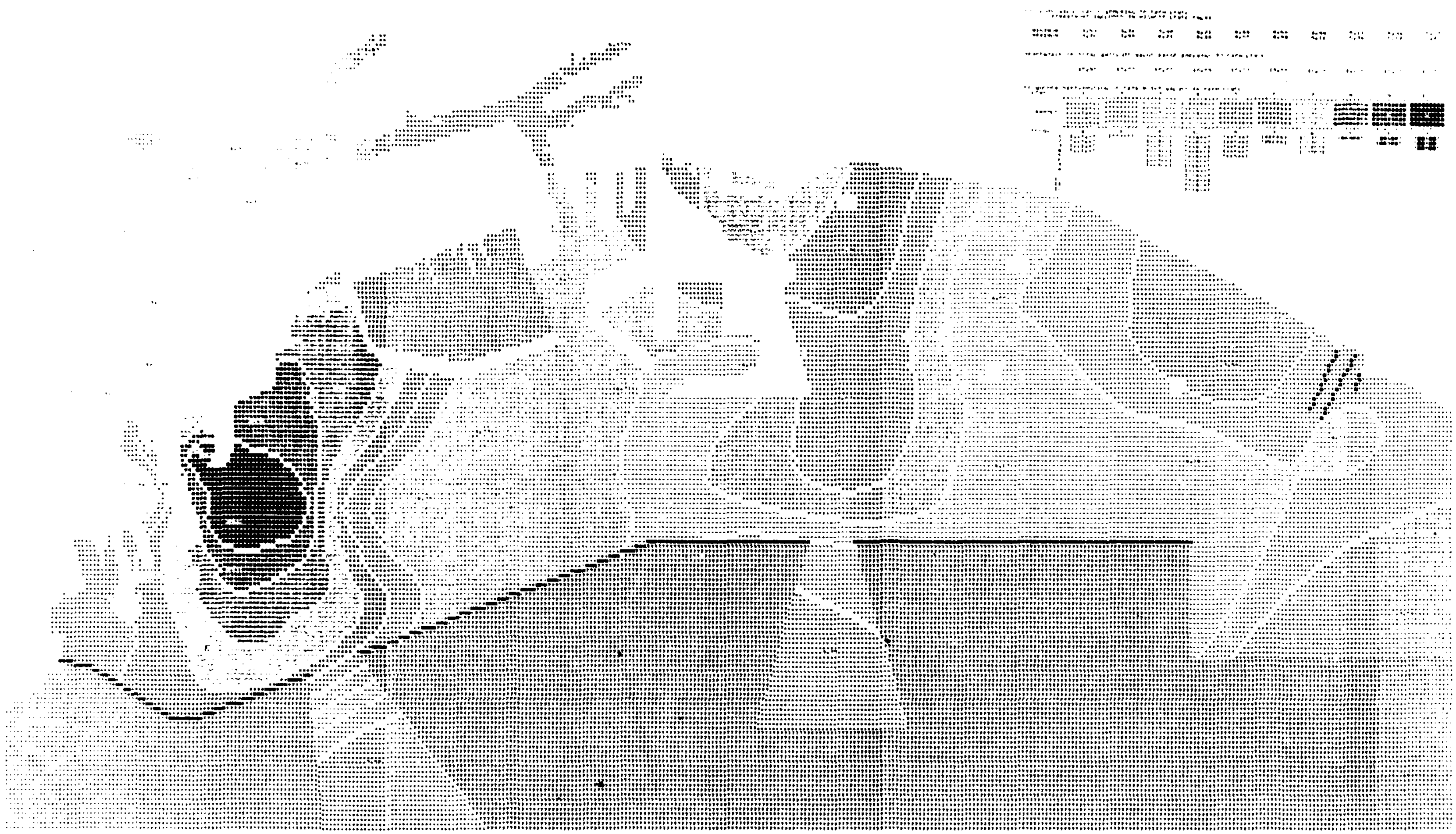
FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
FREQ.	4	1	7	12	5	2	4	1	2	3

```
         1         2         3         4         5         6         7         8         9        10
 1  I..1..I   I''2''I   I--3--I   I==4==I   I++5++I   IXX6XXI   I007OOI   I@@8@@I   I999999I   I■■■■I
 2  I..1..I             I--3--I   I==4==I   I++5++I   IXX6XXI   I007OOI             I999999I   I■■■■I
 3  I..1..I             I--3--I   I==4==I   I++5++I             I007OOI                        I■■■■I
 4  I..1..I             I--3--I   I==4==I   I++5++I             I007OOI
 5                      I--3--I   I==4==I   I++5++I
 6                      I--3--I   I==4==I
 7                      I--3--I   I==4==I
 8                                I==4==I
 9                                I==4==I
10                                I==4==I
11                                I==4==I
12                                I==4==I
```



9.28



Standard Plate Count — 1973
Figure 9.6

Standard Plate Count, 1974

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	3.77	4.00	4.24	4.47	4.70	4.93	5.17	5.40	5.63	5.86
MAXIMUM	4.00	4.24	4.47	4.70	4.93	5.17	5.40	5.63	5.86	6.10

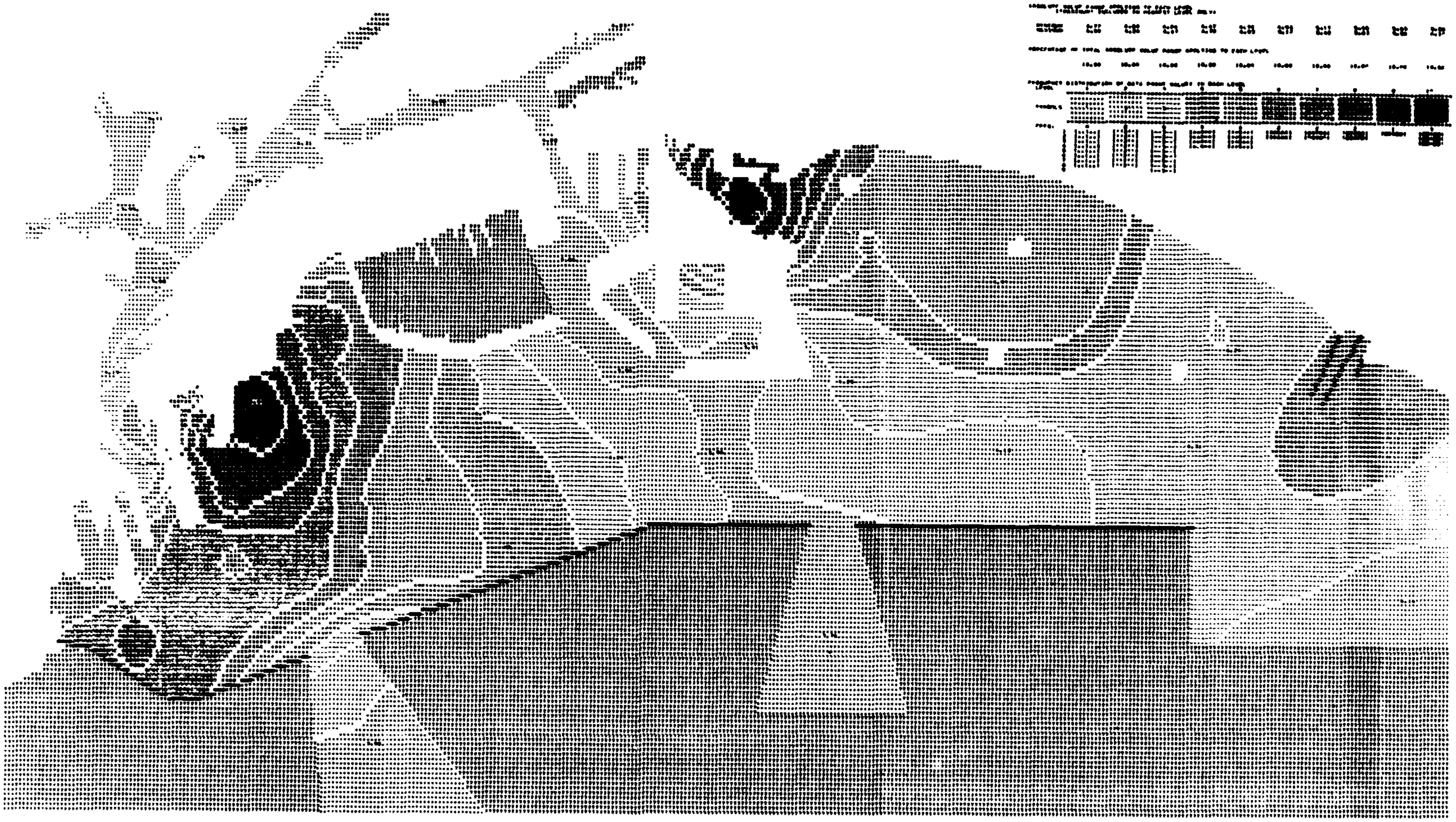
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	••••1••••	''''2''''	----3----	====4====	++++5++++	XXXX6XXXX	OOOO7OOOO	@@@@8@@@@	[illegible]	[illegible]
FREQ.	8	8	9	4	4	2	2	2	1	3

9.30



Standard Plate Count — 1974
Figure 9.7

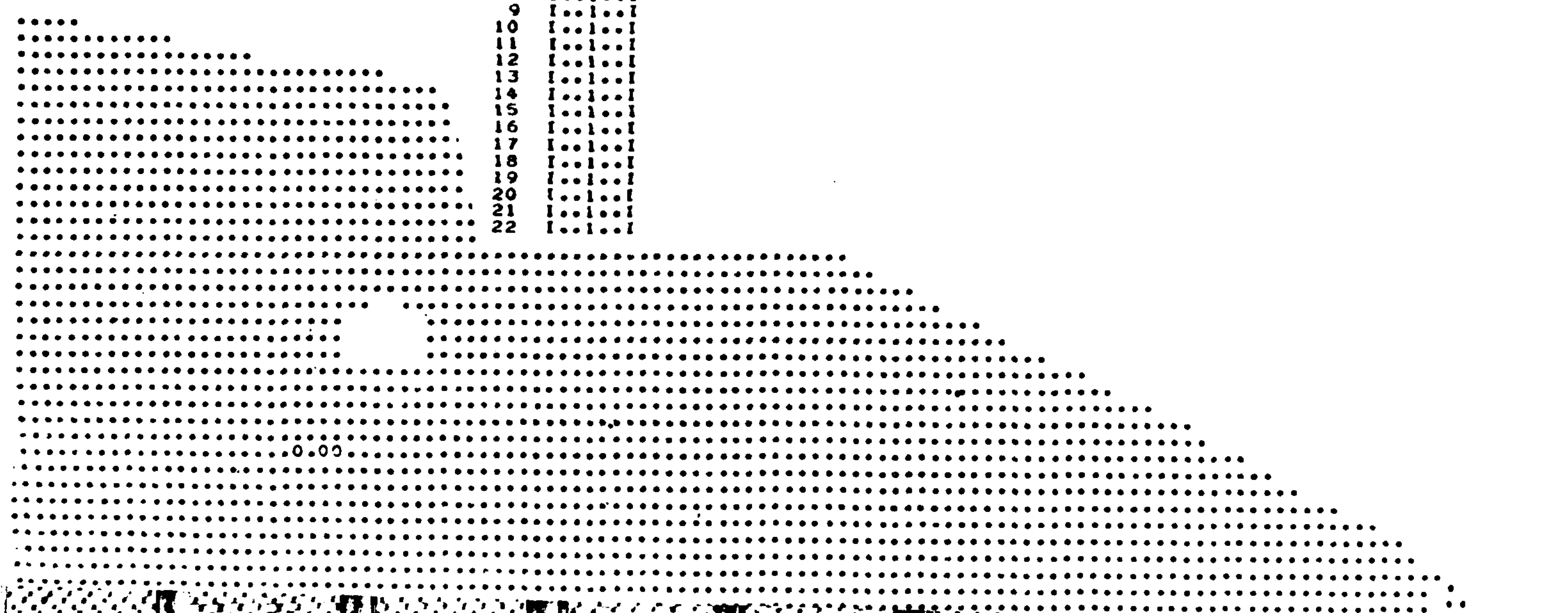
Total Coliforms, 1973

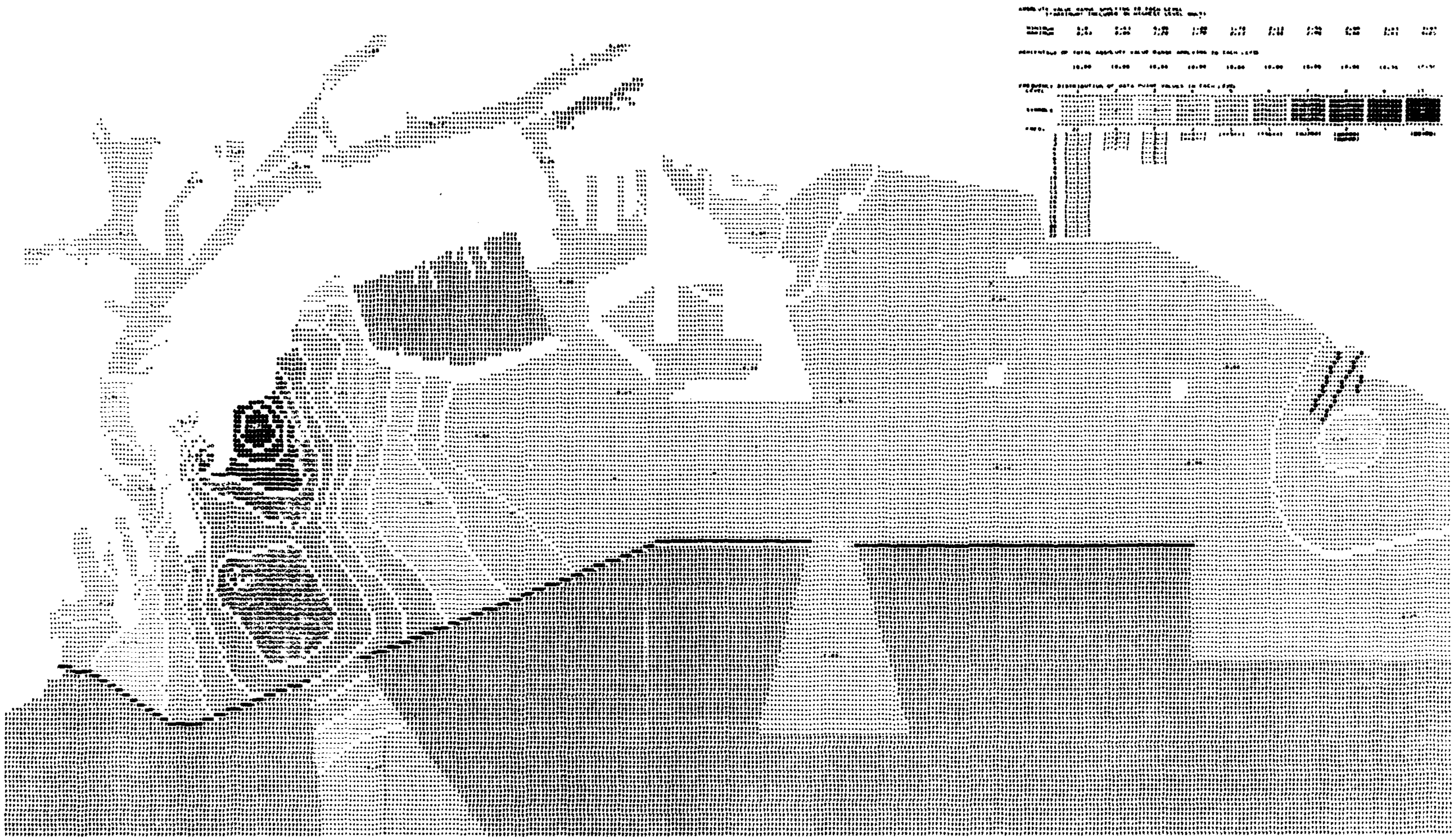
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
MINIMUM	0.0	0.43	0.85	1.28	1.70	2.13	2.55	2.98	3.40	3.83
MAXIMUM	0.43	0.85	1.28	1.70	2.13	2.55	2.98	3.40	3.83	4.25
PERCENTAGE	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
SYMBOLS	....1....	'''2'''	----3----	====4====	++++5++++	XXXX6XXXX	0000700000	88888888	[illegible]	[illegible]
FREQ.	22	4	7	2	1	1	1	2	0	1





Total Coliform — 1973

Figure 9.8

Total Coliforms, 1974

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

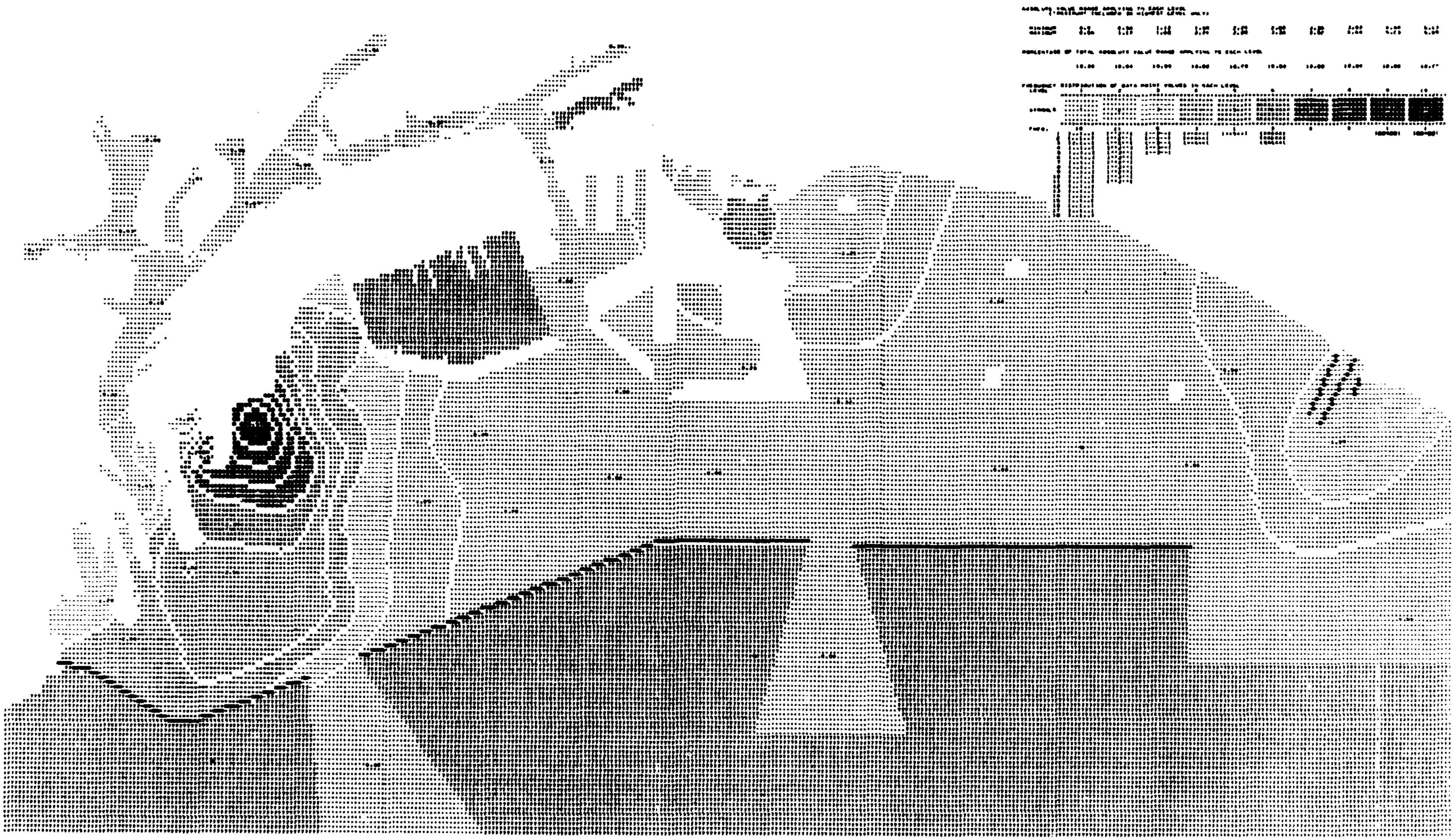
MINIMUM	0.0	0.56	1.12	1.68	2.24	2.80	3.36	3.92	4.48	5.03
MAXIMUM	0.56	1.12	1.68	2.24	2.80	3.36	3.92	4.48	5.03	5.59

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	....1....	''''2''''	----3----	====4====	++++5++++	XXXX6XXXX	000070000	00008000	[illegible]	[illegible]
FREQ.	18	11	5	3	1	3	0	0	1	1



Total Coliform — 1974

Figure 9.9

Fecal Coliforms, 1973

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.0	0.36	0.72	1.08	1.44	1.81	2.17	2.53	2.89	3.25
MAXIMUM	0.36	0.72	1.08	1.44	1.81	2.17	2.53	2.89	3.25	3.61

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

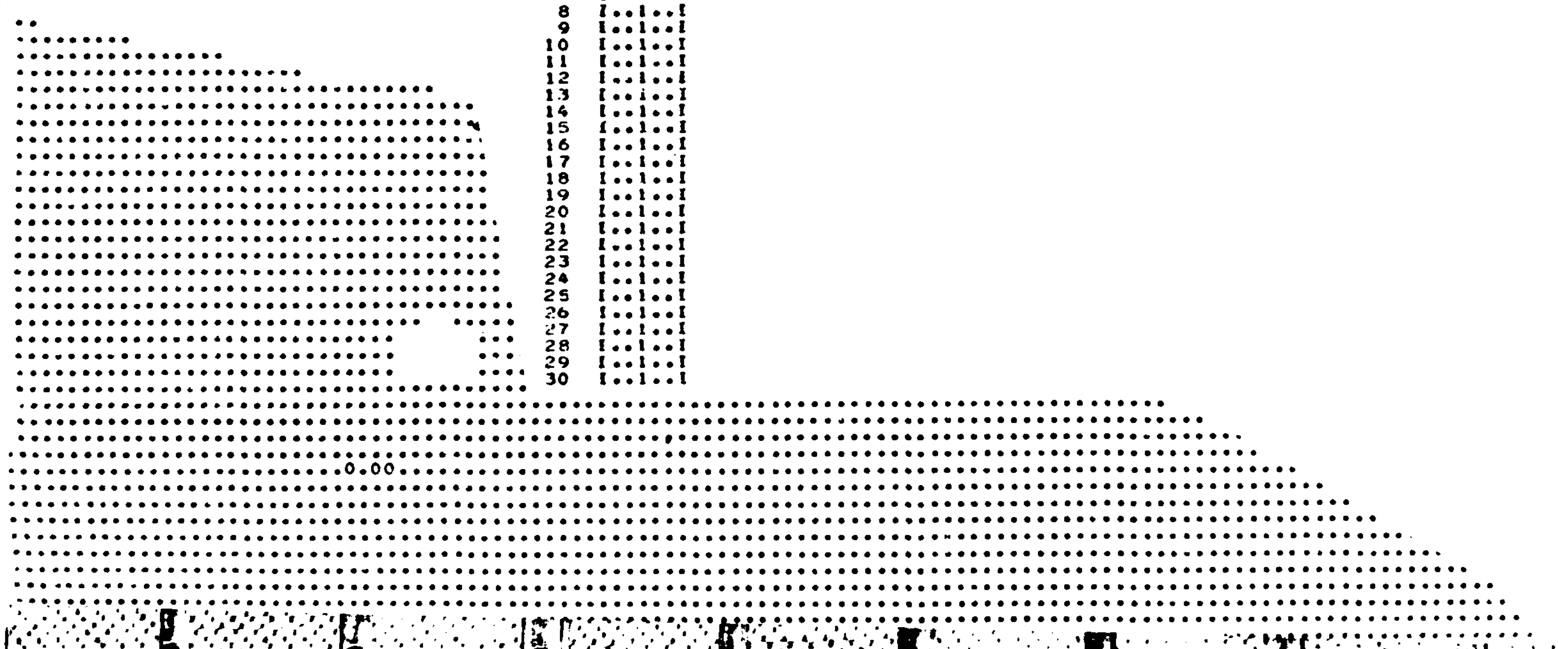
10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

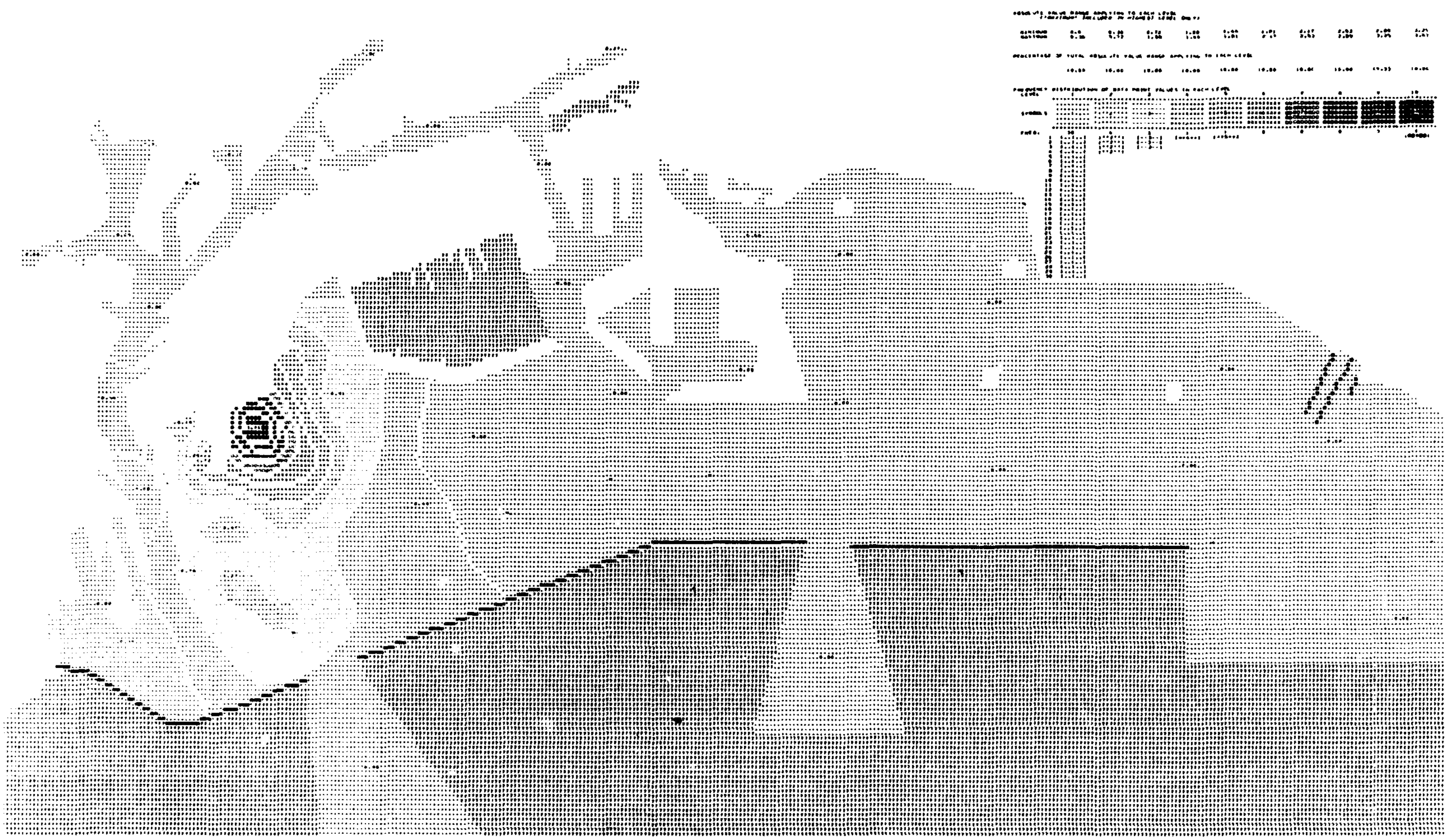
FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	....1....	''''2''''	----3----	====4====	++++5++++	XXXX6XXXX	000070000	[illegible]	[illegible]	[illegible]
FREQ.	30	4	3	1	1	0	0	0	0	1

```
 1  I..1..I  I''2''I  I--3--I  I==4==I  I++5++I                                  [illegible]
 2  I..1..I  I''2''I  I--3--I
 3  I..1..I  I''2''I  I--3--I
 4  I..1..I  I''2''I
 5  I..1..I
 6  I..1..I
 7  I..1..I
 8  I..1..I
 9  I..1..I
10  I..1..I
11  I..1..I
12  I..1..I
13  I..1..I
14  I..1..I
15  I..1..I
16  I..1..I
17  I..1..I
18  I..1..I
19  I..1..I
20  I..1..I
21  I..1..I
22  I..1..I
23  I..1..I
24  I..1..I
25  I..1..I
26  I..1..I
27  I..1..I
28  I..1..I
29  I..1..I
30  I..1..I
```

9.36





Fecal Coliform — 1973

Figure 9.10

Fecal Coliforms, 1974

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.0	0.50	1.01	1.51	2.01	2.52	3.02	3.52	4.03	4.53
MAXIMUM	0.50	1.01	1.51	2.01	2.52	3.02	3.52	4.03	4.53	5.03

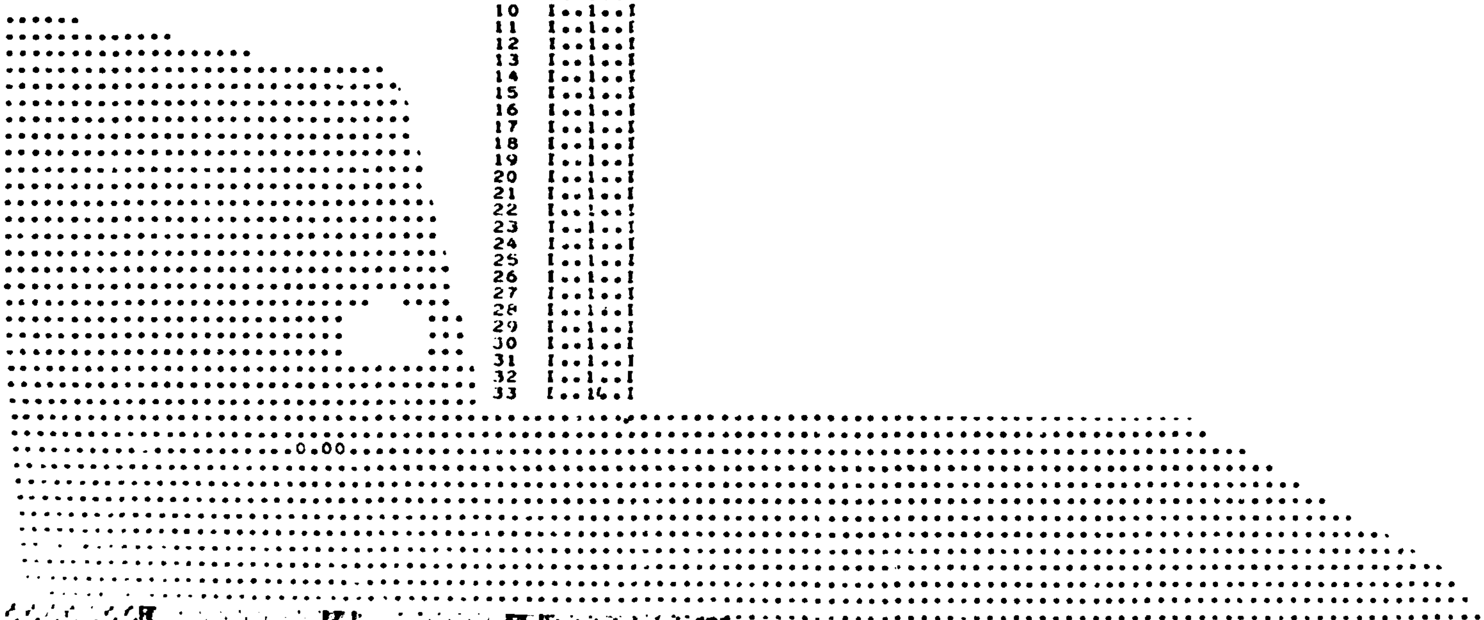
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

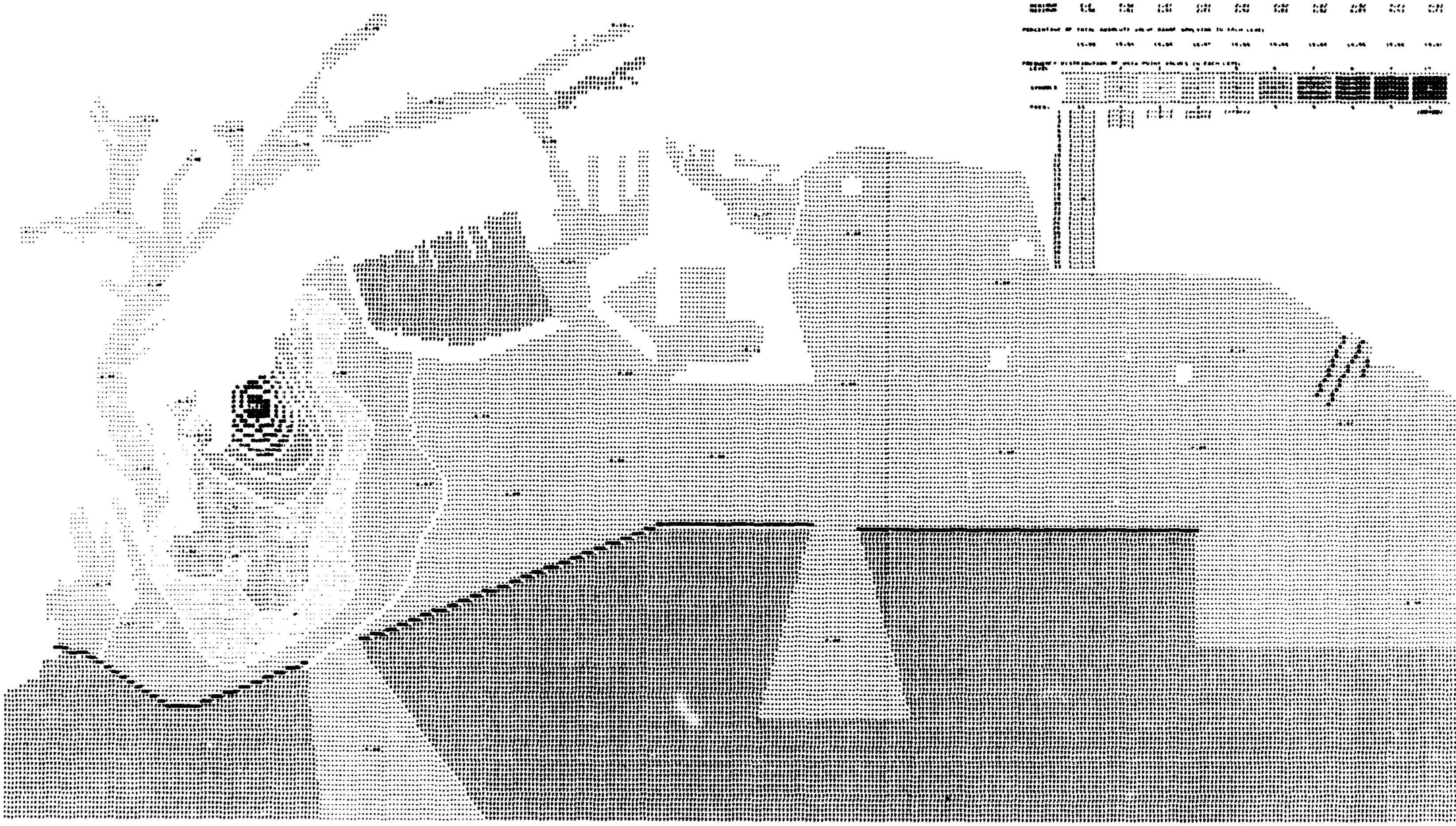
FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	....1....	''''2''''	----3----	====4====	++++5++++	XXXX6XXXX	000070000	888889888	[illegible]	[illegible]
FREQ.	33	4	2	2	1	0	0	0	0	1

```
 1  I..1..I  I''2''I  I--3--I  I==4==I  I++5++I                                      I##*##I
 2  I..1..I  I''2''I  I--3--I  I==4==I
 3  I..1..I  I''2''I
 4  I..1..I  I''2''I
 5  I..1..I
 6  I..1..I
 7  I..1..I
 8  I..1..I
 9  I..1..I
10  I..1..I
11  I..1..I
12  I..1..I
13  I..1..I
14  I..1..I
15  I..1..I
16  I..1..I
17  I..1..I
18  I..1..I
19  I..1..I
20  I..1..I
21  I..1..I
22  I..1..I
23  I..1..I
24  I..1..I
25  I..1..I
26  I..1..I
27  I..1..I
28  I..1..I
29  I..1..I
30  I..1..I
31  I..1..I
32  I..1..I
33  I..1..I
```



9.38



Fecal Coliform — 1974

Figure 9.11

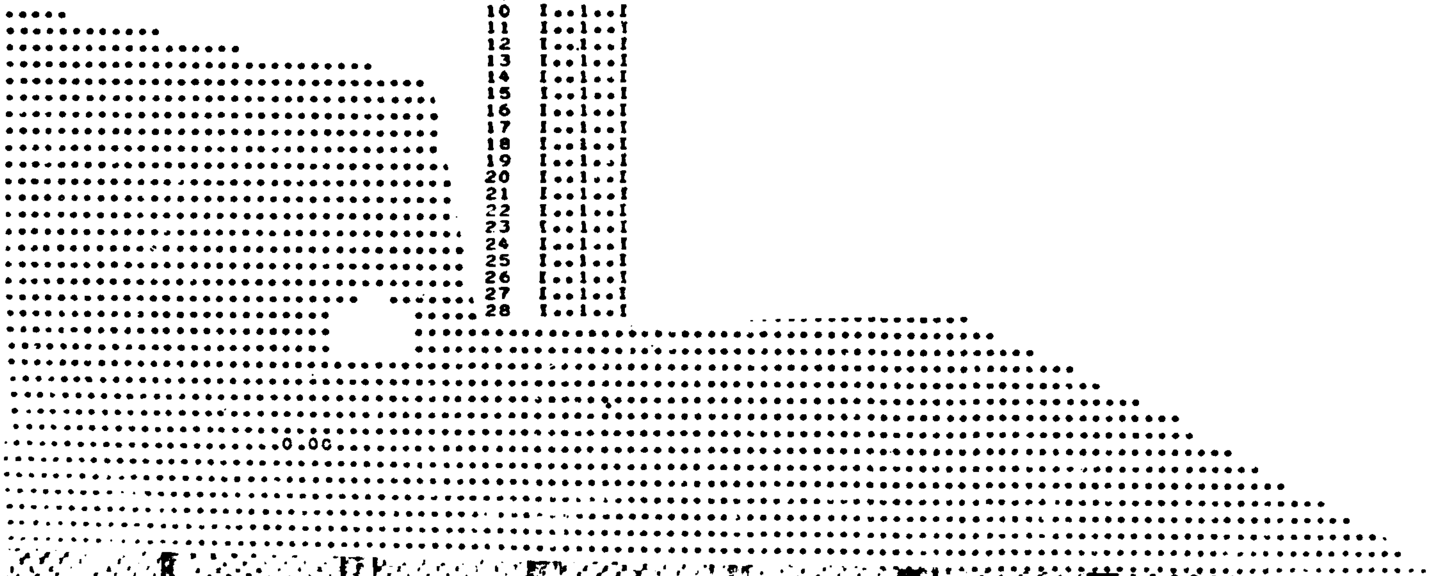
Fecal Streptococci, 1973

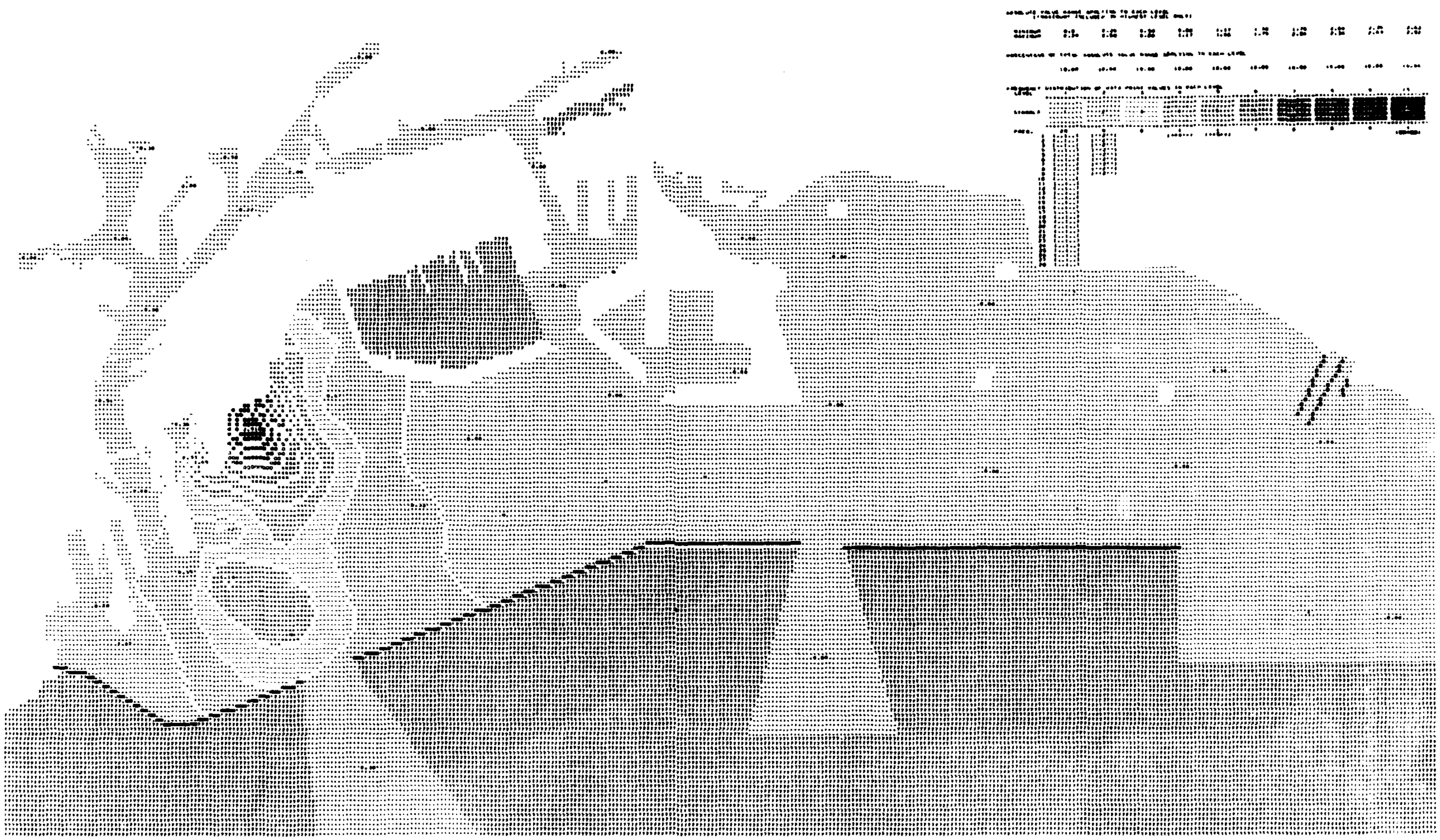
```
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM      0.0        0.29       0.58       0.88       1.17       1.46       1.75       2.04       2.34       2.63
 MAXIMUM      0.29       0.58       0.88       1.17       1.46       1.75       2.04       2.34       2.63       2.92

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

             10.00      10.00      10.00      10.00      10.00      10.00      10.00      10.00      10.00      10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL          1          2          3          4          5          6          7          8          9         10
```

LEVEL	1	2	3	4	5	6	7	8	9	10
MINIMUM	0.0	0.29	0.58	0.88	1.17	1.46	1.75	2.04	2.34	2.63
MAXIMUM	0.29	0.58	0.88	1.17	1.46	1.75	2.04	2.34	2.63	2.92
PERCENTAGE	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
SYMBOLS	....1....	''''2''''	----3----	====4====	++++5++++	XXXX6XXXX	0000700000	8888888888	[illegible]	[illegible]
FREQ.	28	9	0	1	1	0	0	0	0	1

```
 FREQ.        28          9          0          1          1          0          0          0          0          1
      1    I..1..I    I''2''I               I==4==I    I++5++I                                            I88*88I
      2    I..1..I    I''2''I
      3    I..1..I    I''2''I
      4    I..1..I    I''2''I
      5    I..1..I    I''2''I
      6    I..1..I    I''2''I
      7    I..1..I    I''2''I
      8    I..1..I    I''2''I
      9    I..1..I    I''2''I
     10    I..1..I
     11    I..1..I
     12    I..1..I
     13    I..1..I
     14    I..1..I
     15    I..1..I
     16    I..1..I
     17    I..1..I
     18    I..1..I
     19    I..1..I
     20    I..1..I
     21    I..1..I
     22    I..1..I
     23    I..1..I
     24    I..1..I
     25    I..1..I
     26    I..1..I
     27    I..1..I
     28    I..1..I
```

9.40





Fecal Streptococci — 1973

Figure 9.12

Fecal Streptococci, 1974

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.0	0.50	1.01	1.51	2.02	2.52	3.03	3.53	4.03	4.54
MAXIMUM	0.50	1.01	1.51	2.02	2.52	3.03	3.53	4.03	4.54	5.04

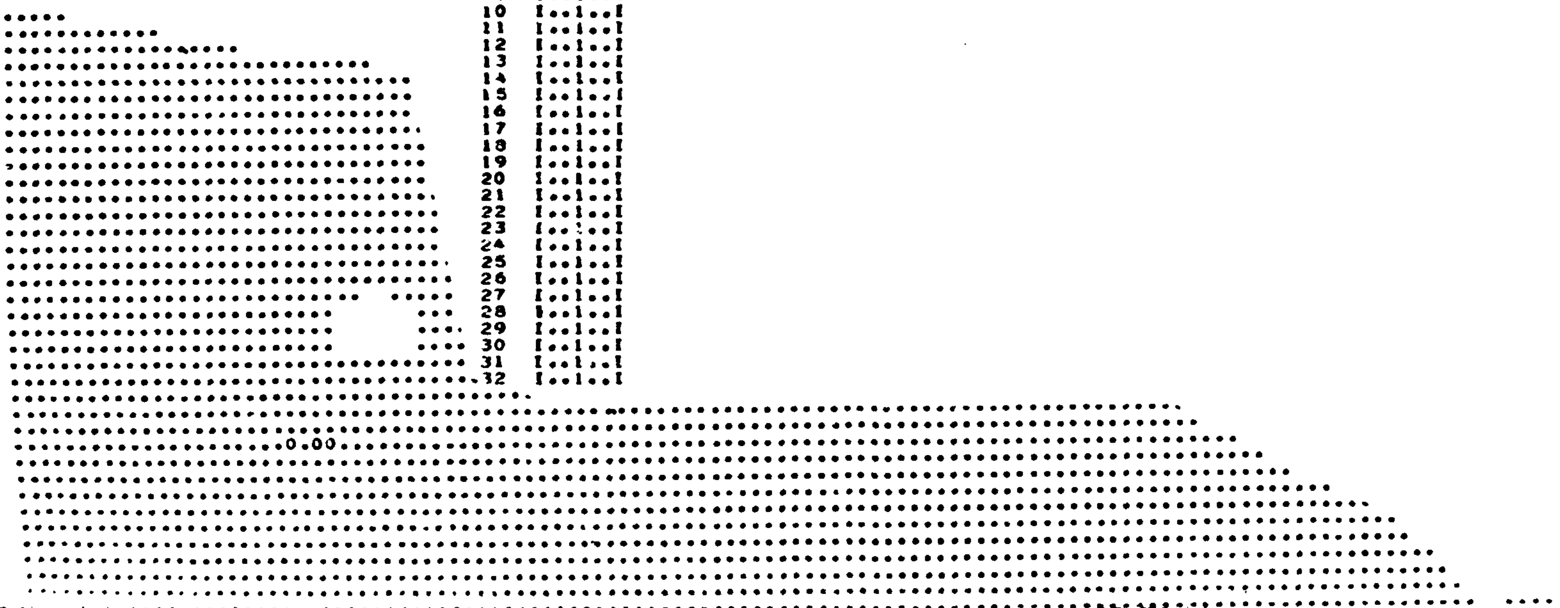
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

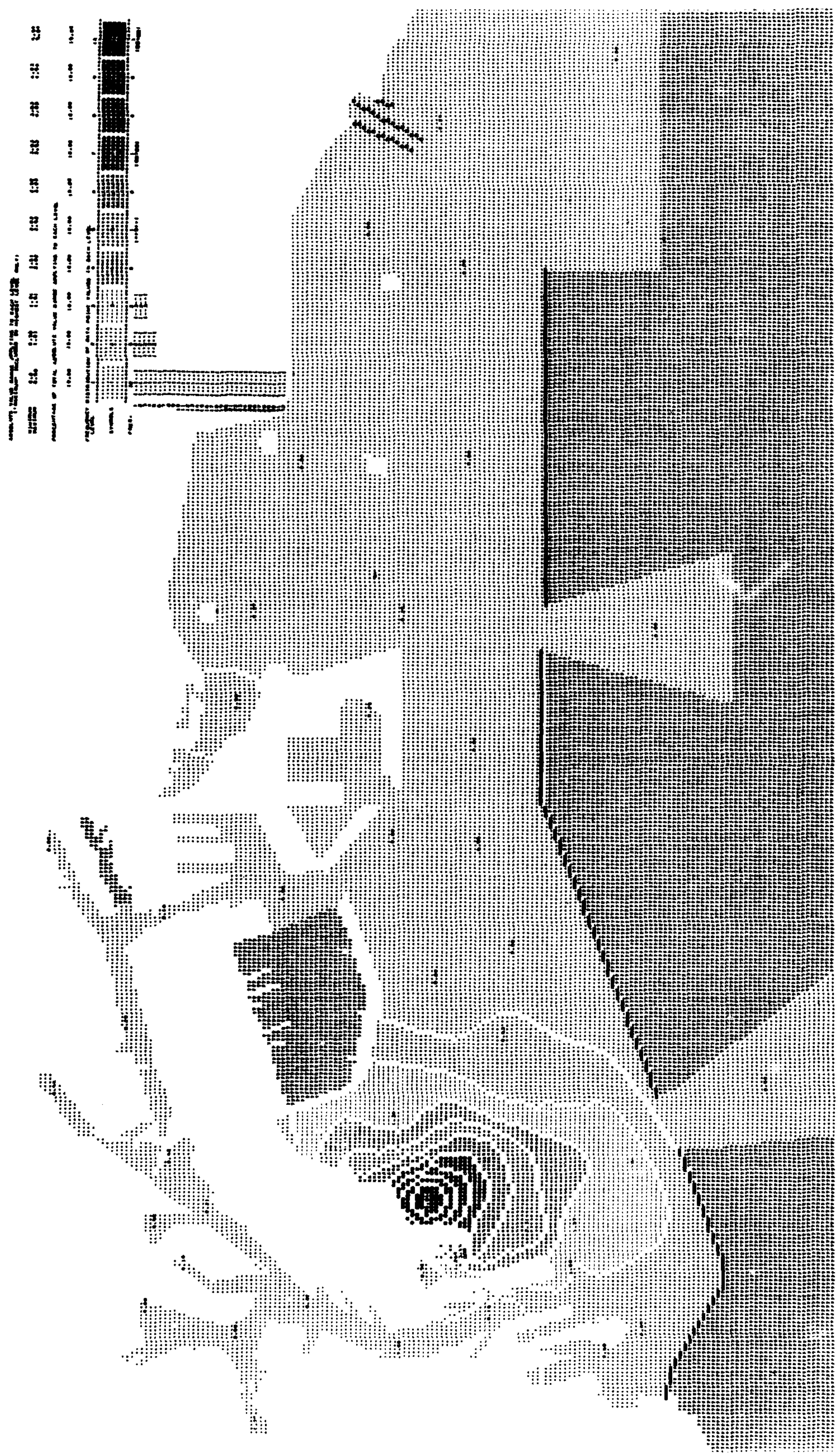
FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
FREQ.	32	5	3	0	1	0	1	0	0	1

```
       1  I..1..I  I''2''I  I--3--I            I++5++I            I007001                     I38+E8I
       2  I..1..I  I''2''I  I--3--I
       3  I..1..I  I''2''I  I--3--I
       4  I..1..I  I''2''I
       5  I..1..I  I''2''I
       6  I..1..I
       7  I..1..I
       8  I..1..I
       9  I..1..I
      10  I..1..I
      11  I..1..I
      12  I..1..I
      13  I..1..I
      14  I..1..I
      15  I..1..I
      16  I..1..I
      17  I..1..I
      18  I..1..I
      19  I..1..I
      20  I..1..I
      21  I..1..I
      22  I..1..I
      23  I..1..I
      24  I..1..I
      25  I..1..I
      26  I..1..I
      27  I..1..I
      28  I..1..I
      29  I..1..I
      30  I..1..I
      31  I..1..I
      32  I..1..I
```



9.42



Fecal Streptococci — 1974
Figure 9.13

Biochemical Oxygen Demand (BOD), 1973

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.45	0.55	0.65	0.74	0.84	0.94	1.04	1.14	1.24	1.34
MAXIMUM	0.55	0.65	0.74	0.84	0.94	1.04	1.14	1.24	1.34	1.4[illegible]

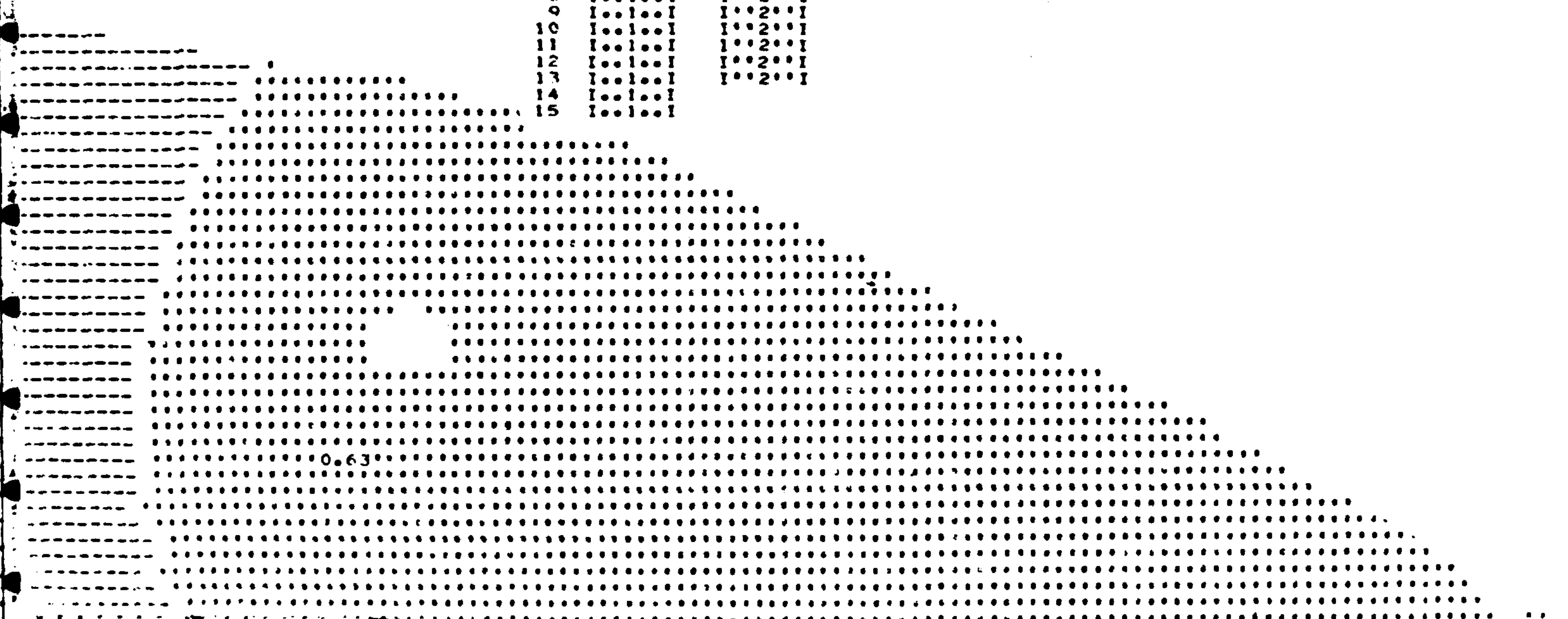
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

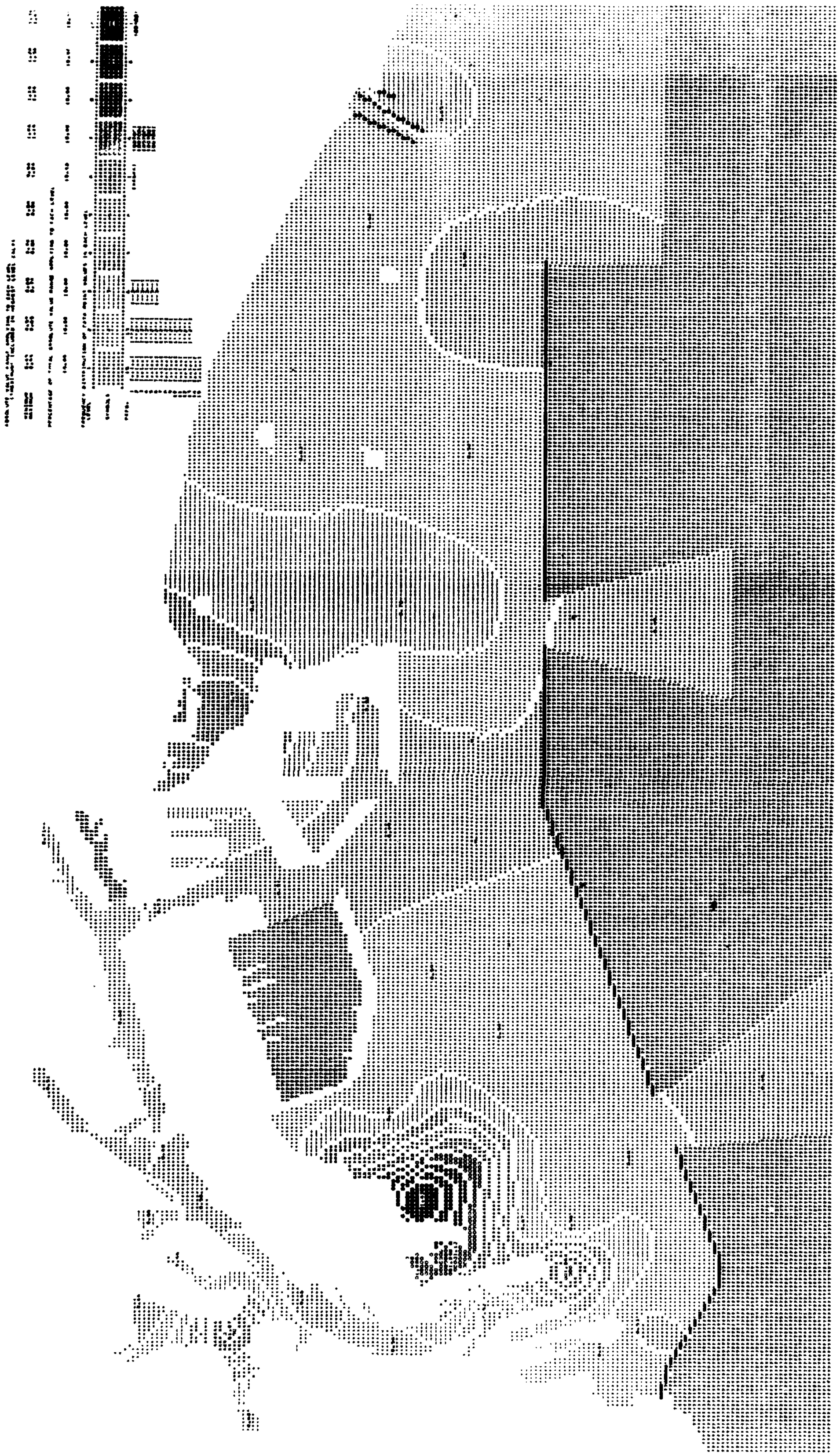
10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

```
LEVEL        1          2          3          4          5          6          7          8          9          10
         ======================================================================================================
         .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  000000000  [illegible] [illegible] [illegible]
         .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  000000000
SYMBOLS  ....1....  ''''2''''  ----3----  ====4====  ++++5++++  XXXX6XXXX  000070000
         .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  000000000
         .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  000000000
         ======================================================================================================
FREQ.        15         13         6          0          0          1          5          0          0          1
```

9.44





BOD - 1973

Figure 9.14

Mean Biochemical Oxygen Demand, 1974

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.75	0.83	0.91	0.99	1.06	1.14	1.22	1.29	1.37	1.45
MAXIMUM	0.83	0.91	0.99	1.06	1.14	1.22	1.29	1.37	1.45	1.53

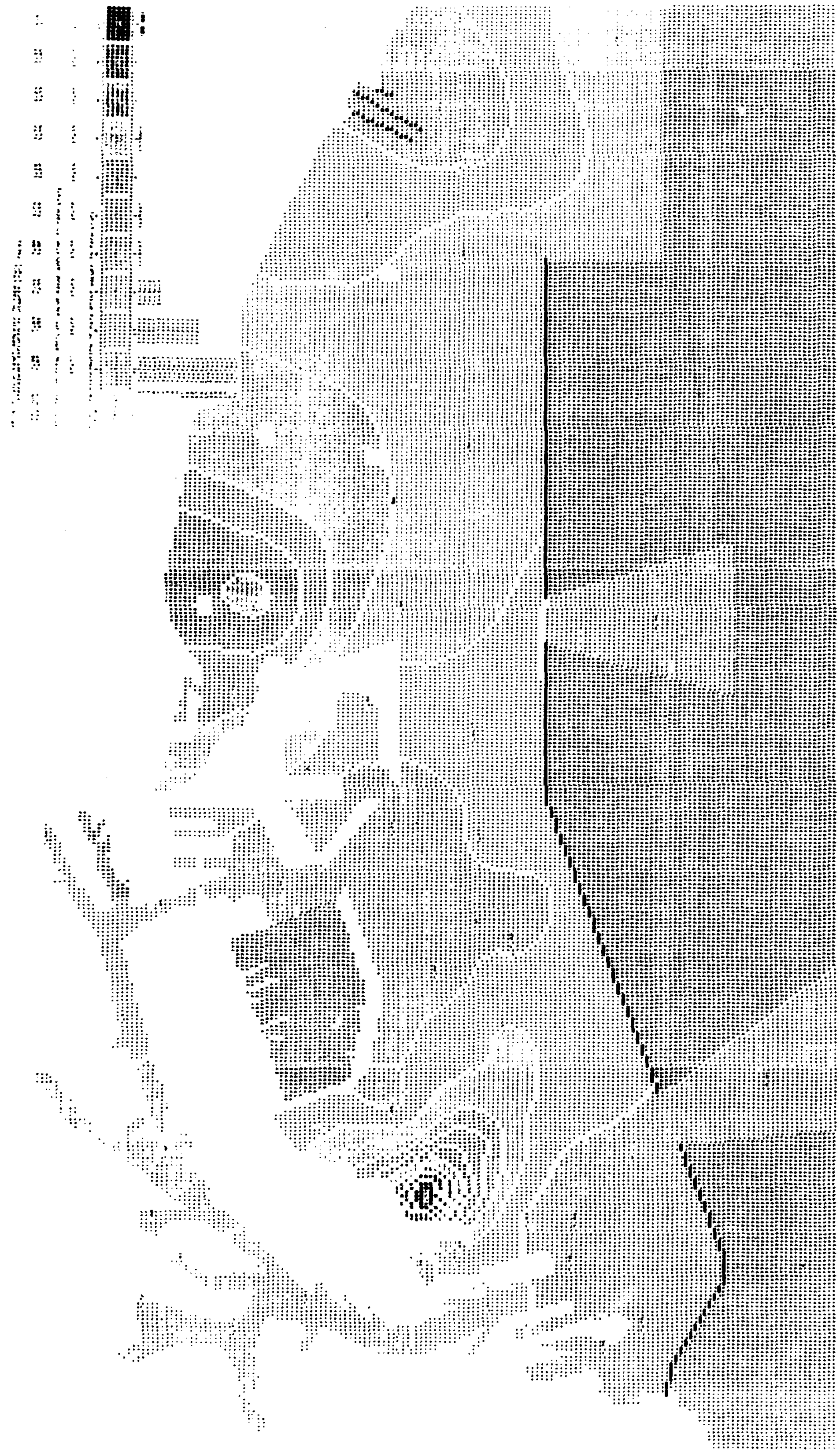
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

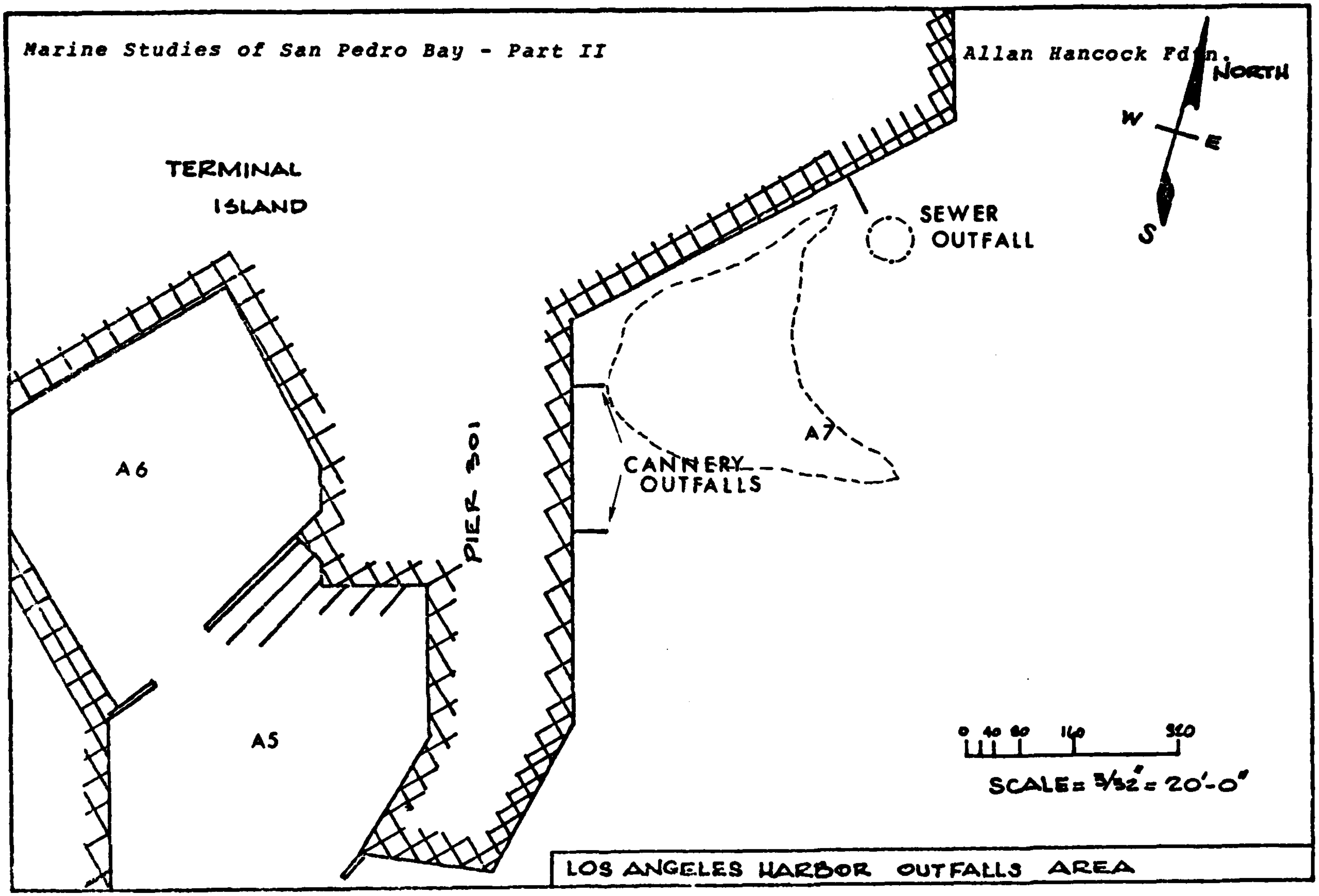
LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	....1....	''''2''''	----3----	====4====	++++5++++	XXXX6XXXX	OOOO7OOOO	@@@@8@@@@	████9████	████1████
FREQ.	21	13	5	1	1	0	1	0	0	1

9.46

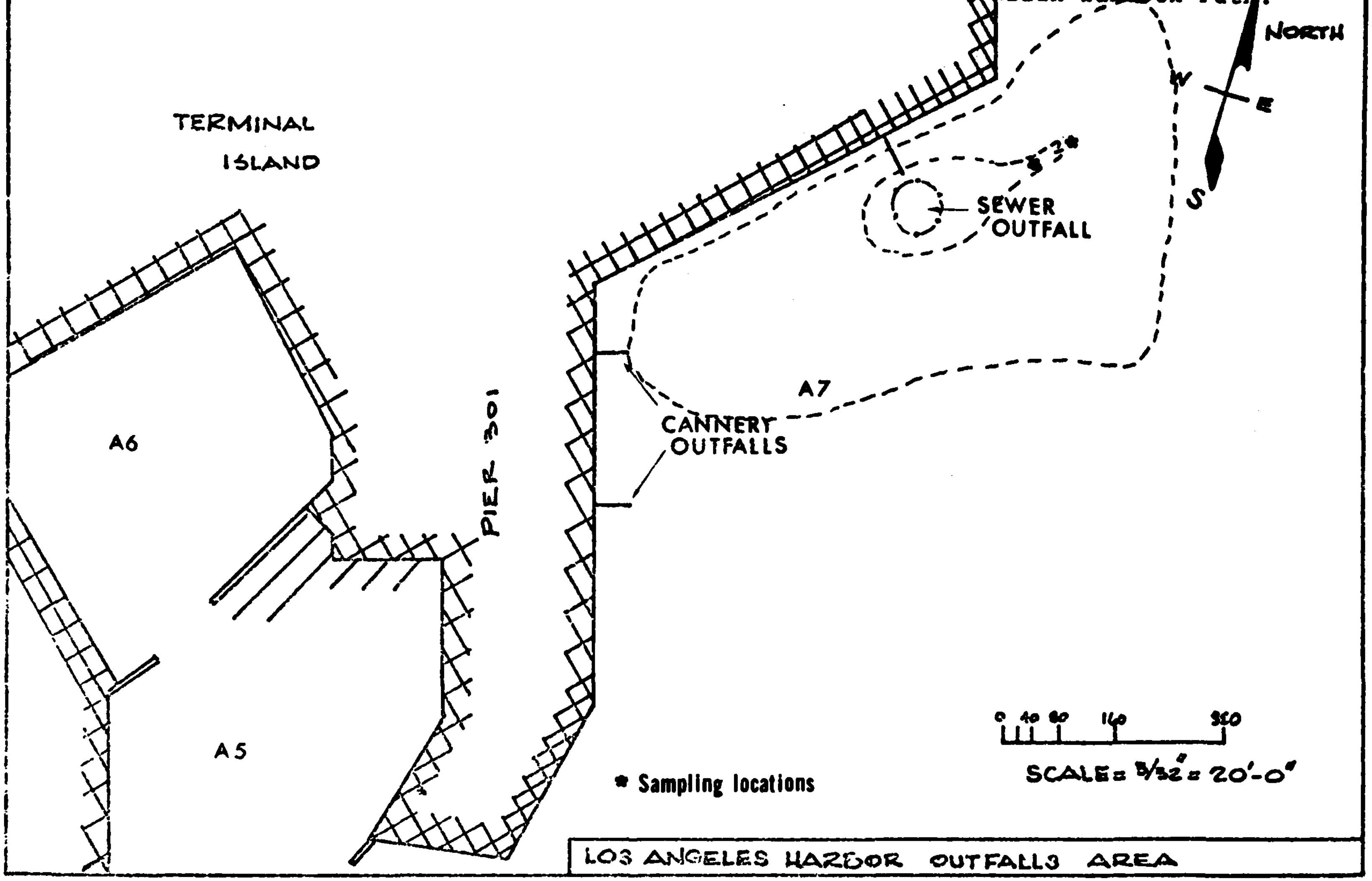


Mean BOD - 1974

Figure 9.15

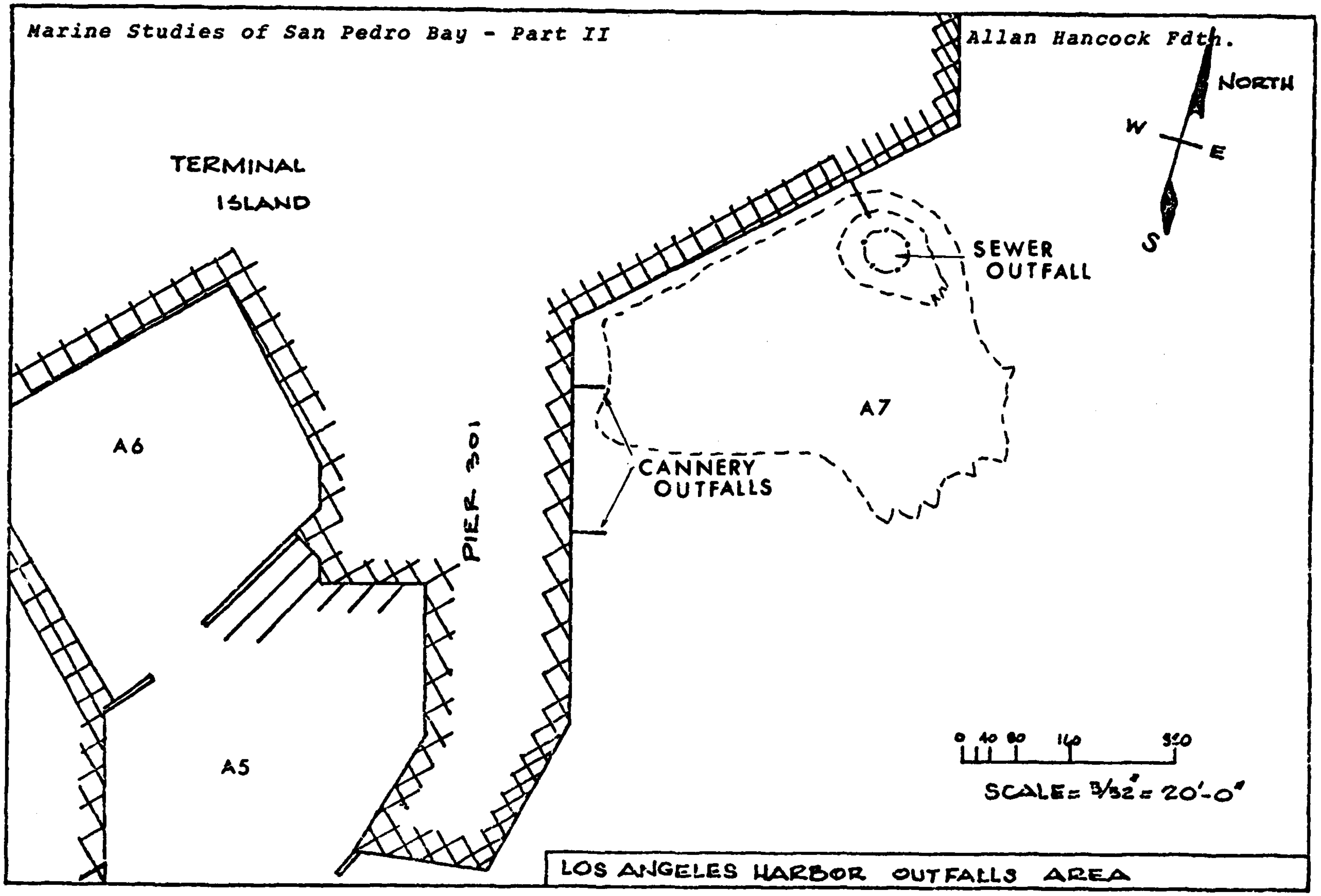


DYE MOVEMENT, 17. July. 1972, --- 1345
Figure 9.16



DYE MOVEMENT, 17. July.1972, --- 1420

Figure 9.17



DYE MOVEMENT, 15. Aug.1972, --- 1300
Figure 9.18

CHAPTER 10

NUTRIENTS IN SURFACE WATERS OF LOS ANGELES-LONG BEACH HARBORS

10.1
NUTRIENTS IN SURFACE WATERS OF LOS ANGELES-LONG BEACH HARBORS

INTRODUCTION

Of the myriad chemical substances found in San Pedro Bay the compounds of phosphate and nitrogen are of particular interest because of their major role in the metabolism of plants and animals. These nutrients also demonstrate the various physical processes of an area as well as the potential productivity during temporal sequences. A deficiency of nutrient substances can be associated with possible low-productivity of organic matter, since phytoplankton utilize nitrogen and phosphate to form amino acids, proteins, and other complex compounds necessary for life processes and they, in turn, affect other life forms (Raymont, 1967). The general relationship between the cycles and seasonal levels of phosphate and nitrogenous compounds in the San Pedro Bay and the general abundance of phyto- and zooplankton has been a matter of concern for many years. Since nutrient elements usually exist in trace amounts, it is quite evident that the various biological, physical, and chemical processes occurring in the harbor can have a large effect on the nutrient concentration and also on the plant and animal life (Riley & Chester, 1971).

NORMAL LEVELS OF NUTRIENTS

Although the concentrations of harbor nutrients are studied in terms of their mean levels in relationship to the whole harbor mean level, it is of some significance to know what "normal" levels are, in order to note the differences between the stations and compare them to "normal" levels described perhaps from other areas and other conditions. The chemistry of the harbor sediments and waters is complex, containing entities, some of which are unknown and will probably remain so. Levels of nutrient concentration change from day to day and are very heavily influenced by the surrounding environment. Thus, there cannot be a "normal" level of nutrients in the harbor because concentrations there are so much higher than those outside the harbor area. Station B1 was a "normal" station or a baseline for comparison, because its nutrient levels are similar to the levels of normal southern California surface seawater of this area. B1 also has lower mean levels of all nutrients when compared to A1 and the other outer stations. Along with a low bacterial count, low BOD's, and high dissolved oxygen (DO) readings, this station is more indicative of the surface waters of the San Pedro Bay coastline. However, this station is still affected by the harbor environment and as such will show differences from waters farther out in the channel. Therefore, upon consideration of the B1 data the following conclusions can be made:

Phosphate. Although this compound is relatively stable as far as seasonal fluctuation is concerned, summer values tend to be low and there is a seasonal winter rise in concentration. The normal reduction in phosphate during spring is associated with the outburst of phytoplankton growth which occurs at that time. The buildup of PO_4 during autumn to an eventual winter maximum is also associated with phytoplankton activity.

The mean concentration of phosphate was 0.57 µg-atoms P/l, with a range from 0.25 to 1.10 µg-atoms P/l.

Nitrate. Always the most abundant chemical entity measured. Close inshore, concentrations may tend to increase and this may be partly a result of land drainage. Early spring concentrations are low until the end of August, after which there is a gradual buildup to the winter maximum (Raymont, 1963).

The mean concentration of nitrate was 3.42 µg-atoms N/l, with a range of 0 to 21.28 µg-atoms N/l.

Ammonia. A very stable entity at B1. Usually very low quantities were present during most of the year with small peaks at various intervals.

The mean concentration of ammonia was 0.41 µg-atoms N/l with a range from 0 to 2.60 µg-atoms N/l.

Nitrite. The maximum levels usually appear in June-September, with the minimum at January-February. The reverse is true at B1 with a winter maximum and a definite minimum during the warmer months.

The mean concentration of nitrite was 0.19 µg-atoms N/l with a range from 0 to 0.46 µg-atoms N/l.

MATERIALS AND METHODS

The analysis of seawater microconstituents utilized by plant and animal life, when at the very great dilution which may occur in the Los Angeles-Long Beach Harbors, involves techniques which have been developed and refined to some degree of precision over the past 25 years. A method which is practical for large scale studies either involves a) being suitable for immediate shipboard analysis at the time the water sample is collected, or b) procedures permit storage and transport of water samples with no appreciable change in the concentration of the constituent to be analyzed. In either event, it is essential that the analysis method be a quick and relatively simple procedure, for in the present survey many stations are sampled in one day.

COLLECTING METHODS

Sampling procedure. Seawater is collected in a plastic bucket that has been rinsed with seawater several times. It is then filtered through 4.25 cm Whatman Glass Filters GF/C grade, utilizing a Millipore filtering mechanism. Once filtered, the seawater is divided up into the various sample bottles from which the Autoanalyzer also receives its sample. The Autoanalyzer utilized only one 250 ml. polyethylene bottle per station from which all the nutrient analysis is derived. Separate containers are used for each of the nutrients in the manual method. For phosphate, a 200 ml. polyethylene bottle with screw-top cap is used and this bottle has been previously treated specially with a solution of iodide in potassium iodide solution (Heron, 1962). Samples for nitrate and nitrite analysis are usually collected in 125 ml. glass Erlenmeyer flasks and covered with Parafilm. Ammonia samples are collected in 125 ml. glass Erlenmeyer flasks that have been washed with dilute hydrochloric acid, and then covered with tinfoil. All bottles and flasks are rinsed several times with seawater before a final sample is taken. Hydrogen sulfide samples are analyzed in situ and therefore no sample containers are needed.

Storage. All samples, except the ammonia, are frozen on board the vessel until transferred to the laboratory freezer. The ammonia samples are kept in a cooler until transferred to the laboratory refrigerator. Once the frozen samples have been thawed, all analyses must be started without delay. Refreezing and thawing of samples will alter results.

ANALYTICAL METHODS

1. Determination of reactive phosphorus. Essentially the same as in Strickland and Parsons (1968) A practical hand - book of seawater analysis, p. 49, except that:

a. 200 ml polyethylene bottles are used instead of 130 ml.
b. Bottles are treated with iodide to reduce bacterial contamination and changes during storage (Heron, 1962).

2. Determination of reactive nitrate. Method of Strickland and Parsons (1968), except:

a. 4 cm. cells are used instead of 10 cm. cells for use in the Beckman DB Spectrophotometer. Accuracy is slightly decreased as is the limit of detection.
b. Cadmium filings must never be exposed to air as it decreases reduction efficiency. (Strickland and Parsons, 1968)

3. Determinations of reactive nitrite. Strickland and Parsons (1968), no exceptions.

4. Determination of ammonia. (Solorzano method, 1969). In addition, a Technicon Autoanalyzer was used to

obtain duplicate values during the latter part of the study. The instrument, property of the Corps of Engineers, was delayed in delivery and was not functional for some months. Further data were obtained through special field runs made to supplement the regular monthly survey of stations.

5. Determination of hydrogen sulfide. Hach Chemical Method. This reliable test for hydrogen sulfide in water will detect as little as 0.1 ppm. However, it has limited effectiveness because sulfides in surface waters are usually below the 0.1 ppm level. (Technicon, 1972; 1973A; 1973B).

RESULTS

Utilizing data collected from surface waters at the various stations in the Los Angeles-Long Beach Harbor complex, computer printouts of the 1973 and 1974 nutrients were obtained and analyzed by three sequential methods:

1) Graph comparisons and/or contrast method. Individual computer graphs from each station were visually compared to stations in the general vicinity in order to notice whether trends and similarities existed.

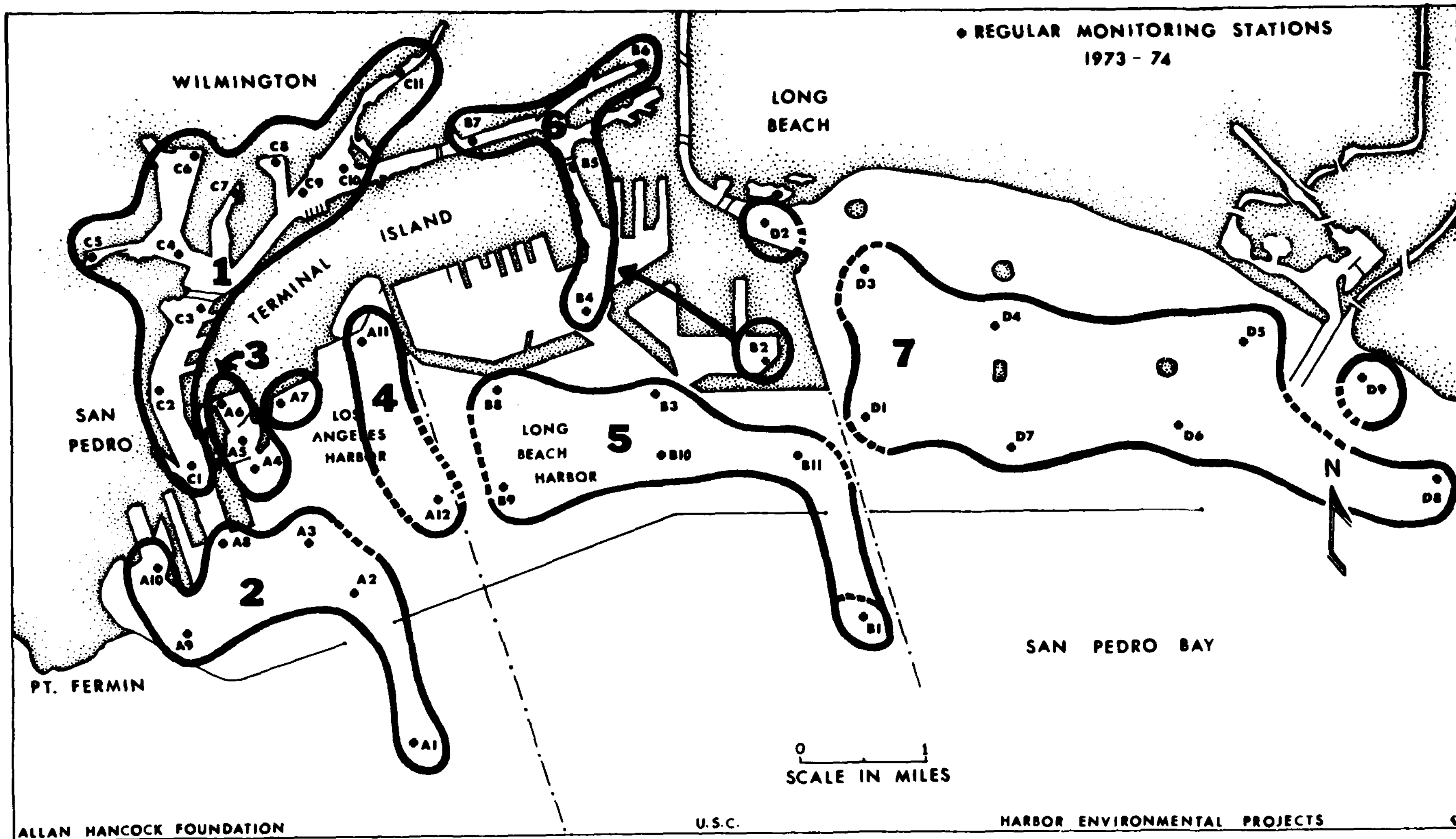
2) Mean Concentration Method. Since there is a large volume of data, the mathematical mean of each individual nutrient was established for each year and the concentrations at each individual station were plotted using standard deviation units. For analysis, information is used from two periods: May, 1973 - January, 1974, and January 1974 - January, 1975. Phosphate was not included from the first period. Also any statement of mean annual concentrations deals only with January 1974 - January, 1975 as the information for the first period does not consist of an entire annual cycle. It must also be noted that B9 through B11 were not sampled in 1973.

3) Nutrient Similarities Grouping. After the mean concentrations for nutrients at each station were calculated and mapped, adjacent bodies of stations which are similar in nutrient cycles and mean concentrations were then grouped. Figure 10.1 shows the groupings delineated by nutrients.

DISCUSSION

(Ranges of mean concentrations of the nutrients for all groups are listed in Table 10.1; see Figure 10.1 for groups).

GROUP 1. This group consists of all C stations, basically an inner harbor group with overall high nutrient values.



NUTRIENT SIMILARITIES GROUPINGS

FIGURE 10.1

Table 10.1. Mean Concentration Ranges of Nutrients in the Los Angeles-Long Beach Harbors. 1974.

GROUP	NUTRIENT	RANGE OF MEAN CONC.
1	PO_4	1.27-2.31 µg-atoms P/l
	NO_3	5.30-8.40 µg-atoms N/l
	NO_2	0.35-0.70 µg-atoms N/l
	NH_3	2.59-5.61 µg-atoms N/l
2	PO_4	0.46-1.113 µg-atoms P/l
	NO_3	7.24-13.86 µg-atoms N/l
	NO_2	0.12-0.81 µg-atoms N/l
	NH_3	1.60-5.84 µg-atoms N/l
3	PO_4	1.22-1.75 µg-atoms P/l
	NO_3	6.26-6.95 µg-atoms N/l
	NO_2	0.30-0.35 µg-atoms N/l
	NH_3	6.10-11.93 µg-atoms N/l
4	PO_4	0.90-1.12 µg-atoms P/l
	NO_3	8.70-8.84 µg-atoms N/l
	NO_2	0.20-0.23 µg-atoms N/l
	NH_3	3.10-4.81 µg-atoms N/l
5	PO_4	0.57-1.48 µg-atoms P/l
	NO_3	2.86-4.16 µg-atoms N/l
	NO_2	0.19-0.30 µg-atoms N/l
	NH_3	0.41-1.50 µg-atoms N/l
6	PO_4	0.92-1.48 µg-atoms P/l
	NO_3	5.05-8.91 µg-atoms N/l
	NO_2	0.34-0.52 µg-atoms N/l
	NH_3	3.02-8.41 µg-atoms N/l
7	PO_4	0.75-1.40 µg-atoms P/l
	NO_3	1.52-4.55 µg-atoms N/l
	NO_2	0.16-1.00 µg-atoms N/l
	NH_3	0.48-8.09 µg-atoms N/l
A7*	PO_4	4.03 µg-atoms P/l
	NO_3	7.63 µg-atoms N/l
	NO_2	0.31 µg-atoms N/l
	NH_3	29.73 µg-atoms N/l
D2*	PO_4	1.80 µg-atoms P/l
	NO_3	6.00 µg-atoms N/l
	NO_2	1.69 µg-atoms N/l
	NH_3	18.50 µg-atoms N/l
D9*	PO_4	5.27 µg-atoms P/l
	NO_3	5.66 µg-atoms N/l
	NO_2	0.66 µg-atoms N/l
	NH_3	13.30 µg-atoms N/l

* No range due to the fact that these groups consist of single stations.

Phosphate. Concentrations at all stations had mean values between 1.27 and 2.31 μg-atoms P/l, which as a whole is higher than any other group in the harbor. All stations have two peak periods of high PO_4 concentrations, one in late 1973, early 1974, and one around September-October, 1974. This is normal because of the winter maxima of nutrients and the immense amount of land run-off due to heavy rains of December-January, 1973 and late 1974. Highest stations in PO_4 concentration were C11 and C8, with a maximum value achieved at C11 of 3.80 μg-atoms P/l. A value of 13.67 μg-atoms P/l was registered one day for C8, but this may be due to contamination of the sample during analysis. Most areas of this group have low circulation and thus may tend to accumulate organic matter and other pollutants for a longer period of time than some of the more active areas of the harbor. C1 is a unique station in that it shows a similar PO_4 level with A8 and has a tendency to be a transitional site between the outer A stations of Group 2 and the inner stations of Group 1.

Nitrate. Nitrate concentrations peaked three times during the 1973-1974 winter and once at the end of 1974. C10 had the highest concentration, with a registered high of 32.30 μg-atoms N/l which is also the high for the harbor. This is a confined area with extensive run-off and waste input. In enclosed areas, nitrate concentration may tend to increase and this may partly be a result of land drainage (Raymont, 1963).

Unlike phosphate, nitrate readings at C1 are quite different from those at A8, suggesting differences in source and distribution of this nutrient between the two adjacent stations.

Nitrite. Nitrite was generally average or above the average for the harbor in Group 1 with two peak periods, one in late 1973 and the other in late 1974. The mean concentration is between 0.35 and 0.70 μg-atoms N/l, with a highest concentration of 0.70 μg-atoms N/l at C11. The highest monthly reading comes from C8 with a concentration of 1.73 μg-atoms N/l during late 1973 and late 1974. High nitrite concentrations seem to be extensively centered around C10 and C11, which are areas of freshwater run-off, industrial waste, and possibly raw sewage from boats in the marine areas. These concentrations tend to decrease toward the outer harbor where more mixing occurs. The lowest mean concentration in Group 1 occurs at C1, where it mixes with water from Group 2 outer harbor stations.

Ammonia. This nutrient was at mean concentrations of 2.59 to 5.51 μg-atoms N/l, much like the rest of Los Angeles Harbor. Maximum mean values were achieved at C10 and C11 with means of 4.81 and 5.51 μg-atoms N/l, respectively. Lowest mean concentrations are at C5 with a mean value of 2.59 μg-atoms N/l and the maximum monthly value seen in Group 1 was obtained at C11 with 13.50 μg-atoms N/l.

These concentrations suggest that the ammonia decreases in the deadend slip areas of Group 1 and also decreases toward outer harbor waters.

GROUP 2. Consists of A1, A2, A8, A9, and A10. This in turn could be divided into two subgroups isolating A9 and A10, but for simplicity the group has been kept whole. Even though A1 is farther from the rest of the stations, it is still probably linked to it chemically and physically. In Group 2 there is no clear pattern of nutrients that can be easily distinguished except that levels diminish in concentration towards A1.

Phosphate. Readings are rather stable all year long with minor fluctuations. Mean concentrations are between 0.46 and 1.113 µg-atoms P/l for A1 and A10, respectively. Concentrations tend to decrease toward A1. Possible sources of PO_4 are the Marina at A10 and the high phosphate area of A7 and A4. Highest monthly concentration was obtained at A10 with a reading of 3.66 µg-atoms P/l.

Nitrate. All stations peaked twice between December, 1973 and May, 1974, with higher peaks in the inner stations and decreasing ones toward A1 and A3. Mean concentrations range from 7.24 to 13.96 µg-atoms N/l at A3 and A10, respectively, the latter of which is the highest for the harbor. Highest monthly concentration was recorded at A10 with a reading of 59.26 µg-atoms N/l, although it must be noted that all stations were close to this during the month of January, 1974, following extensive rainfall. Station A10 had a second high peak during winter, 1974 which suggests that it is the major source, or location, of nitrate for the outer harbor, although others such as A7 tend to have an additive effect on the adjacent waters. No explanation is available at this time for such a nitrate source.

Nitrite. Tended to be average to below average for the harbor with concentrations decreasing as A1 is approached. Mean concentrations ranged from 0.12 to 0.81 µg-atoms N/l at A1 and A3, respectively. In February, 1974, nitrite readings of 7.91 µg-atoms N/l were obtained from A3. This is probably an error; otherwise, A3 would have a mean concentration lower than others. Therefore, A10 probably has the highest NO_2 concentration source with a mean of 0.37 µg-atoms N/l. This would also be similar to the nitrate levels relative to nitrogenous compounds other than ammonia. The NO_2 data graphs tend to support this because those of stations A1, A2, and A3 show smooth curves and are related, but toward A10, the NO_2 readings become more erratic and tend to approach the final sharp dips and peaks of A10.

Ammonia. Mean NH_3 concentrations peaked at A8 with a reading of 5.84 µg-atoms N/l and decreased to 1.60 µg-atoms N/l at A1. The highest monthly reading was in June, 1974 of 28.6 at A8, which is close to the mean annual 1974 concentration of A7. Ammonia probably comes from A7 at the sewer outfall, moves toward A4 and on to A8. It disperses into A9 and A10 areas, or there may be other sources. Stations A2 and A3 are affected to a much lesser degree. This would support the concept that A3 and A2 are related to A12, and are in an intermediate group between the rest of the stations in Group 2, Group 4, and station A1. All Group 2 stations tend to peak slightly during winter 1973, but the graphs become erratic between A8, A9 and A10. This crosses the main channel and tidal flushing may cause the similarity in readings. A1 is a more open station and is affected to a lesser extent than the inner stations.

GROUP 3. This group is a small, relatively enclosed area consisting of A4 through A6. Phosphate and nitrate decrease from the maxima at A4 to the minima at A6, showing that those nutrients diffuse into A6 from the outer stations. Station A4 is an intermediate station located on the mean nutrient flow that goes from A7 to A4, and to A8. As would be expected, its concentrations are intermediate between A7 and A8.

Phosphate. The concentrations of phosphate range from 1.22 to 1.75 µg-atoms P/l at A6 and A4, respectively. Maximum values of 5.64 up-atoms P/l were obtained at A4 in March, 1974. Both A5 and A6 have smooth PO_4 curves and show higher tendencies during winter seasons, but A7's curve is extremely erratic and may show the influence of the cannery and sewer outfalls at A7.

Nitrate. The concentrations of nitrate range from 6.26 to 6.95 µg-atoms N/l, showing little differences in nitrate concentrations of this area. All NO_3 curves are almost identical, each consisting of high winter values and low summer values. The highest monthly value was registered at A4 with 31.93 µg-atoms N/l in January, 1974, following heavy winter rains.

Nitrite. Average harbor nitrite concentrations are similar to those of the rest of the harbor. Contrary to phosphate and nitrate, nitrite tends to be of higher overall concentration inside Fish Harbor than outside at A4. This may represent the reducing bottom and low exchange of water in Fish Harbor. Mean annual concentration range is 0.30 to 0.35 µg-atoms N/l at A4 and A5, respectively.

Ammonia. This nutrient is undoubtedly carried successively into A4, A5 and A6, outside the direct influence of A7. A mean concentration went from 11.93 at A4 to 6.10 µg-atoms N/l at A6. Station A4 shows a strong link to the A7 and A8 complexes.

GROUP 4. This group consists of A11 and A12 as a minor intermediate zone between Group 5 and Group 2. There is a small seasonal effect from A7 on A11, and a lesser effect on A12. This area shows concentrations of nutrients intermediate between the lower concentrations of Group 5 and higher concentrations of Group 2.

GROUP 5. This group includes stations from the Long Beach Harbor district in the outer harbor or outside it (B1, B3, B8 through B11).This area has relatively light concentrations of nutrients and there is good mixing with relatively little pollution input. It has very similar values to Group 7, although the latter group has major sources of nutrient inflow (D2, D9). Group 5 has been tentatively linked with B1 because of the close similarities of the latest data, although earlier data was inconclusive. Stations B8 and B9 appear to be linked to Group 4 (A11, A12) when using 1973-1974 data, but remain in Group 5 overall. Station B11 seems to be similar also to D1, but it is probable that the area of B11 and D1 is an intermediate zone between Groups 5 and 7, thus having characteristics of each.

Phosphate. These levels are generally the lowest found in the entire harbor. Mean concentrations range from 0.57 to 1.48 µg-atoms P/l. The 0.80 mean at B8 probably relates directly to the phosphate concentration at A12 of 0.90 µg-atoms P/l. This would suggest that there is a PO_4 link between them and also help support the idea that Group 4 is a transitional group. The PO_4 curves for Group 5 are relatively flat and are basically similar for the individual stations involved. No seasonal variation can be seen, but late 1974 values show an increase which would be in accordance with phytoplankton growth cycles (Raymont, 1963).

Nitrate. These curves maximize at several erratic peaks during winter months of 1973-1974 and then taper off into spring and summer minima. This is followed by a small 1974 winter peak. There are similarities between adjacent Group 4 and Group 7 stations, with possible links with them also. Mean values range from 2.86 to 4.16 µg-atoms N/l which is the lowest for all groups except Group 7 stations.

Nitrite. These levels are average to below average, for the harbor. Mean concentrations increase toward B2 and B4, suggesting that the inner harbor areas are sources of NO_2 addition to Group 5 stations. The NO_2 curve for Group 5 tends to be smooth, with a small increase in the winter of 1973 and an erratic pattern during 1974. Mean concentrations range from 0.19 to 0.30 µg-atoms N/l with the lowest at B1 and highest at B3.

Ammonia. Values show a rather flat curve except for erratic peaks during the winter of 1973 and early 1974. Mean concentration ranged from 0.41 to 1.50 µg-atoms N/l for B1 and B3, respectively, also suggesting that the inner harbor is the source for NH_3 which gradually diffuses into lesser concentrations toward the breakwater entrance. Again, there are transitional zones between Group 4 and Group 7.

GROUP 6. A rather heavily polluted area consisting of wastes from marinas and docks, industrial pollutants, storm drains and cooling waters. Low circulation and retention of surface materials due to the predominant winds, causes this area to rate high in mean nutrient concentration. This group consists of B5, B6, and B7, as well as B2, which is not actually a part of the interior complex, but due to its enclosed location tends to have similarities to the rest of the group.

Phosphate. Mean concentrations were average for Group 6 as a whole, ranging from 0.92 to 1.48 µg-atoms P/l, with the low at B4 and the high at B6. High PO_4 no doubt originates in B7 and B6 areas, and the adjacent Slip 1, diffusing or flushing the PO_4 mean at B2 of 1.02 µg-atoms P/l is higher than the outside waters. No seasonal variation is seen; most of the graphs become more erratic moving toward B6 and B7.

Nitrate. Mean concentrations increase from average to above average readings toward B7 and B6 from the outer stations suggesting, as in PO_4, that these are source areas for NO_3. Mean concentrations range from a low of 5.05 at B4 to a high of 8.91 at B6. B2 also has a higher mean concentration of NO_3 than the outer waters. Nitrate curves tend to peak sharply during winter season and drop off in the summer months.

Nitrite. Curves show a winter high and warmer season low at B2 and B4 thus suggesting that they are under the influence of B3 waters. Stations B5 through B7 showed little seasonal variation; NO_2 concentrations steadily declined through 1973 and most of 1974 but began to increase in late 1974. Nitrite readings at the last three stations are also somewhat erratic. Mean concentrations range from 0.34 µg-atoms N/l at B4 to 0.52 at B5 and B7.

Ammonia. Mean concentrations range from 3.02 to 8.41 µg-atoms N/l at B4 and B5 respectively, suggesting that NH_3 also flows out into the harbor from interior stations. Graphs become more erratic and peaked, moving inward to the B5, B6, and B7 area from the south. No seasonal variations can be noted.

GROUP 7. Stations include D1, D4 through D8, and the D3 transition site. This group is below average for all nutrients due perhaps to dispersal from currents or to rapid utilization of nutrients in the area. If it were not for the D2 nutrient source, the concentrations would be well below their present means. Extensive phytoplankton blooms occur in the area.

Phosphate. Mean concentrations range from 0.75 to 1.40 μg-atoms P/l at D1 and D7, respectively. PO_4 concentrations show a link between D2 and D9 with diffusion areas at D3, D5, and D6. Graphs show some winter peaks and summer minima at a few stations, but on the whole, PO_4 values seem to be different at most Group 7 stations due to unknown factors.

Nitrate. This is one of the nutrients that shows a direct link between D2 and the other outer stations. It occurred in below average concentrations throughout Group 7. A sharp peak is evidenced at D3 on January 1974, and this coincides with heavy rains and effluent from D2 during that time. Graphs for NO_3 tend to peak softly during winter periods and reach minima at irregular intervals. Mean concentrations ranged from 1.52 at D8 to 4.55 μg-atoms N/l at D3.

Nitrite. Values gave a mean concentration ranging from 0.16 at D5 to 1.00 μg-atoms N/l at D3, and were generally average for this area, with major influence from the D2 source. As with NO_3, D3 is a transitional zone showing close relationship to D2. No seasonal variation was seen in the graphs.

Ammonia. Shows influences from D2 and D9 in Group 7, with mean NH_3 concentrations between 0.48 to 8.09 μg-atoms N/l. Although D8 does not seem to be greatly influenced by other nutrients from D9, it is strongly affected by NH_3 diffusion. This is an example of diffusion where NH_3 does not break down readily into NO_2 or NO_3 and tends to stabilize in ammonia compounds. Graphs tend to become erratic approaching either D2 or D9 from the south or southwest.

STATION A7. This station is grouped alone, being unique in that all concentrations of nutrients are high, but the PO_4 and NH_3 concentrations are completely out of proportion to the other stations in the adjacent area. Two cannery outfalls and the effluent from primary-treated sewage are dumped in the area. This station has nutrient concentrations which are among the highest in the entire harbor, although high mean or peak values may be found elsewhere, without comparable explanations.

Phosphate. This station has the second highest mean PO_4 concentration in the harbor next to D9, with a reading of 4.03 μg-atoms P/l and a range from 0.58 to 17.17. The graph is erratic and shows no seasonal tendencies. These high PO_4 concentrations are normal with areas of outfalls and run-off. Station D9 is at the mouth of the San Gabriel River, and receives warm water effluents and run-off.

Nitrate. Relatively the same as other adjacent stations. The winter peaks are sharp and the summer concentrations are very low in comparison, which may reflect the seasonality of cannery waste and run-off. Mean concentration of 7.63 with a range of 0.12 to 36.83 µg-atoms N/l.

Nitrite. This nutrient occurs in moderate concentrations during the year. No seasonal variation can be seen. Mean concentration is 0.31 µg-atoms N/l with a range of 0.01 to 0.97 ug-atoms N/l.

Ammonia. Occurs in the highest concentration in the harbor at A7. During the period May, 1973 through January, 1974, it reached a mean of 57.94 µg-atoms N/l and in 1974, after a lower winter concentration, a mean of 29.0 ug-atoms N/l was found for the May-December period. The range for May, 1973 through January, 1974 is 3.60 to 126.90 µg-atoms N/l and the range for 1974 is 3.68 to 83.40 µg-atoms N/l. The peak periods are during the summer and fall months and decline during winter and spring. This could be related to differences in process of various types of fish according to fishing seasons and to subsequent release of free amino acids and other nitrogenous compounds in the effluents. The release of ammonia occurs largely from the bacterial decomposition of organic material (Barnes, 1957). Ammonia is usually associated with sewage effluents but dissipates into the atmosphere or by diffusion fairly rapidly.

STATION D2. As one of the source areas for all of the nutrients, D2 showed above average concentrations due to land run-off and pollution further up the flood control channel. This station had the highest mean concentrations of all parameters at all D stations except for PO_4 at D9, and thus probably dictates what the concentrations at Group 7 stations will be. Except for the usual erratic behavior of ammonia, all nutrients tended to peak during the fall-winter months and reach minima during spring and summer.

STATION D9. This station is isolated from adjacent station groups, in the same manner that A7 and D2 are separated. As a source area for the eastern portion of Group 7, station D9 is high in NH_3 and PO_4. Thermal discharges , freshwater run-off, and industrial wastes affect the properties of the nutrients in that area. All nutrient graphs are extremely erratic and no seasonal variation is seen.

Figures 10.2 to 10.8 present the means of the data for nutrient concentrations found during this study and discussed above.

LITERATURE CITED

Barnes, H. 1957. Nutrient elements. in Treatise on marine ecology and paleoecology. J.W. Hedgpeth (ed.). Vol. I, Geol. Soc. Amer. Memoir 67:297-344.

Hach Chemical Co. Water analysis procedures. Hydrogen sulfide. Catalog No. 8. Hach Chem. Co., Ames, Iowa. 92 pp.

Harvey, H.W. 1969. The chemistry and fertility of seawaters. Cambridge Univ. Press. 240 pp.

Heron, J. 1962. Determination of phosphate in water after storage in polyethylene. Limnol. and Oceanog. 7(3):316-321.

Raymont, J.E.G. 1963. Plankton and productivity in the oceans. Pergammon Press, New York. 660 pp.

Riley, J.P. and R. Chester. 1971. Introduction to marine chemistry. Academic Press, New York. 465 pp.

Solorzano, L. 1969. Determination of ammonia in natural waters by the phenolhypochorite method. Limnol. and Oceanogr. 14: 799-801.

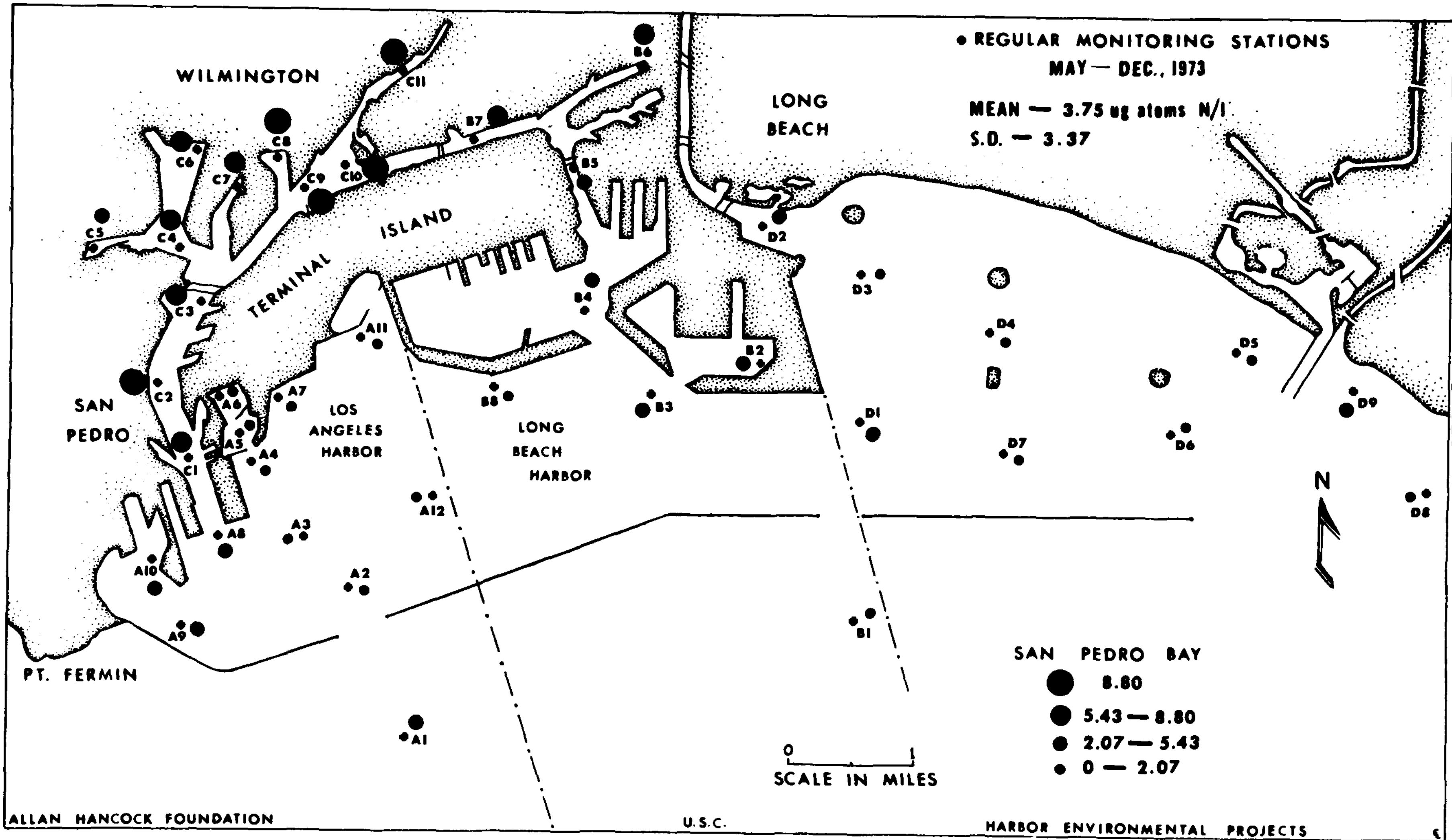
Soule, D.S. and M. Oguri. 1972. Circulation patterns in Los Angeles-Long Beach Harbor. in Marine Studies of San Pedro Bay, California. Part I. Allan Hancock Fdtn., and Office of Sea Grant. University of Southern California. 113 pp.

Strickland, J.D.H. and T.R. Parsons. 1968. A practical handbook of seawater analysis. Fish. Res. Bd. Canada Bull. 167. 311 pp.

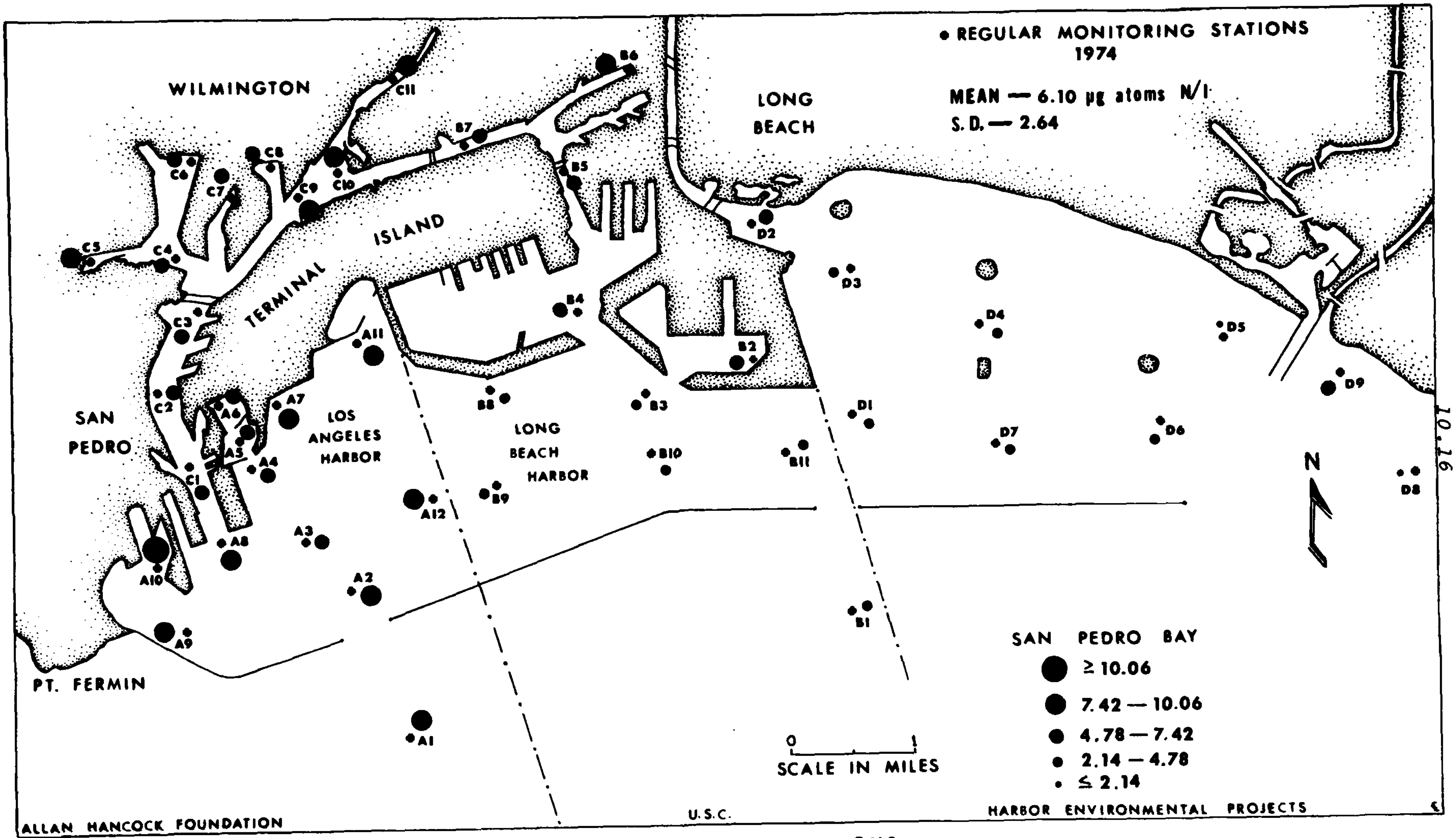
Technicon Autoanalyzer II. 1972. Nitrate and nitrite in water and seawater. Industrial Method 158-71 W/ Preliminary. 3pp.

________________ 1973A. Orothophosphate in water and seawater. Industrial Method 155-71 W/ Tentative. 3pp.

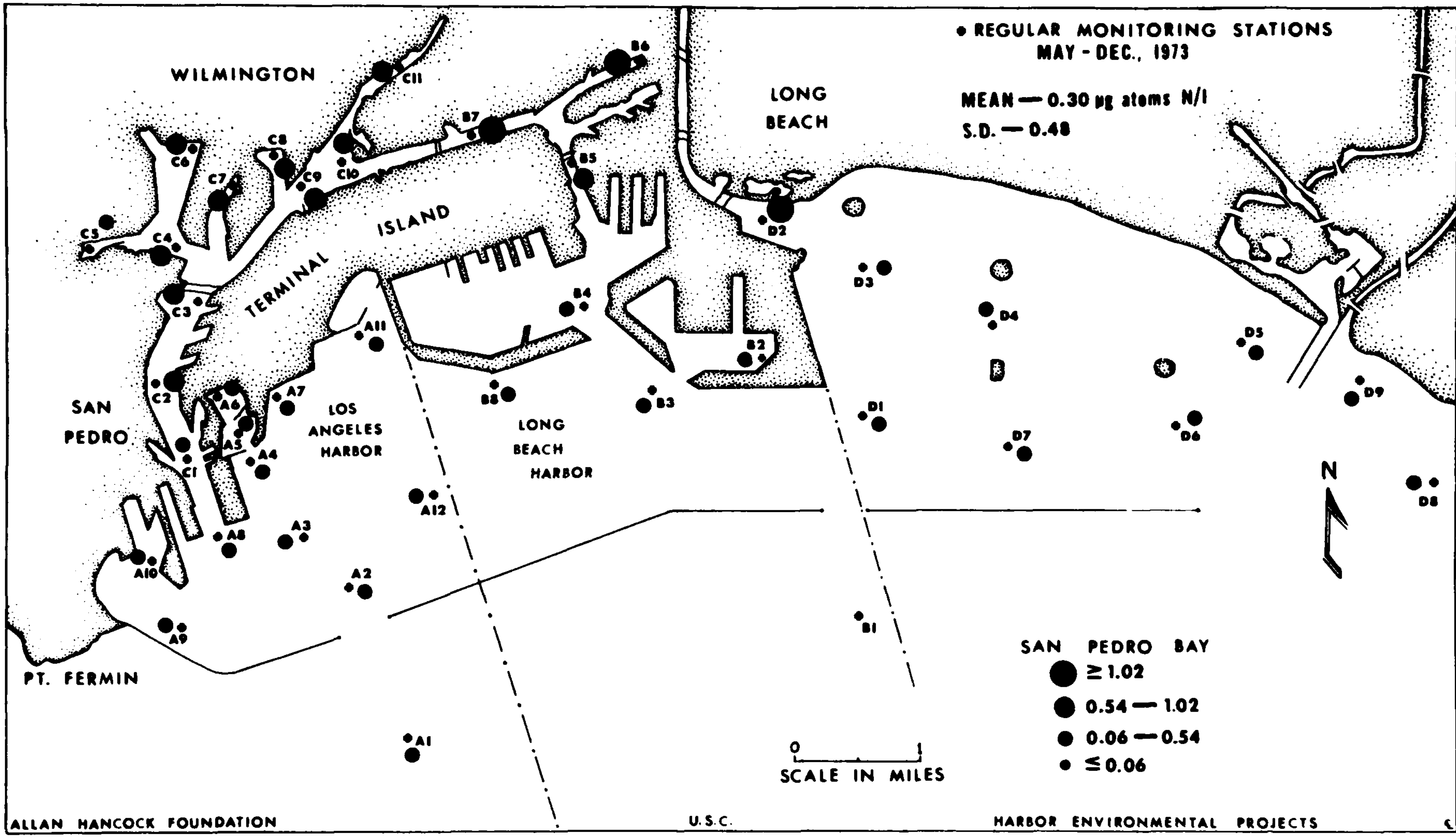
________________ 1973B. Nitrite in water and seawater. Industrial Method 161-71 W/ Tentative. 2pp.



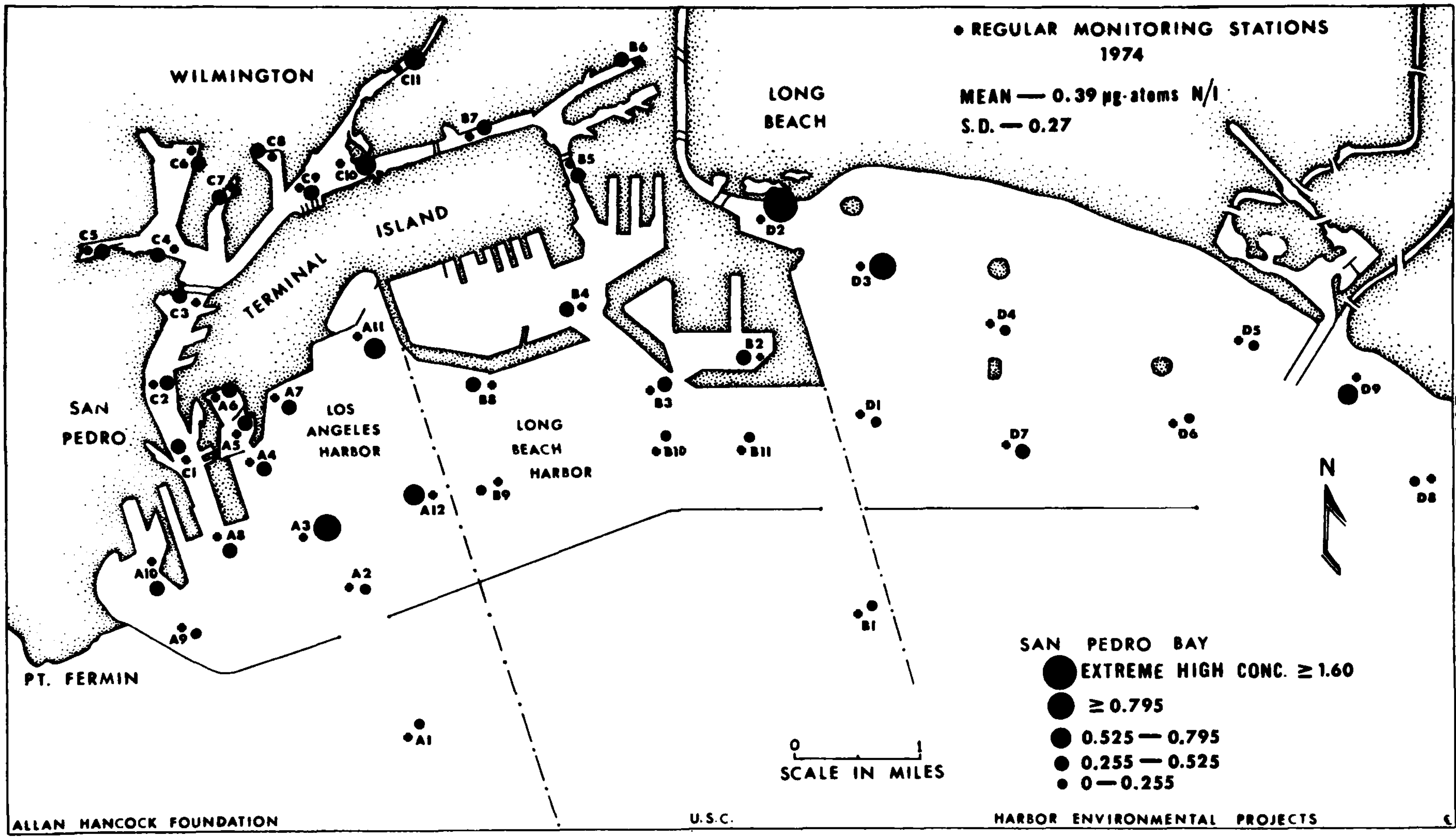
1973 NITRATE CONCENTRATIONS
Figure 10.2



1974 NITRATE CONCENTRATIONS
Figure *10.3*

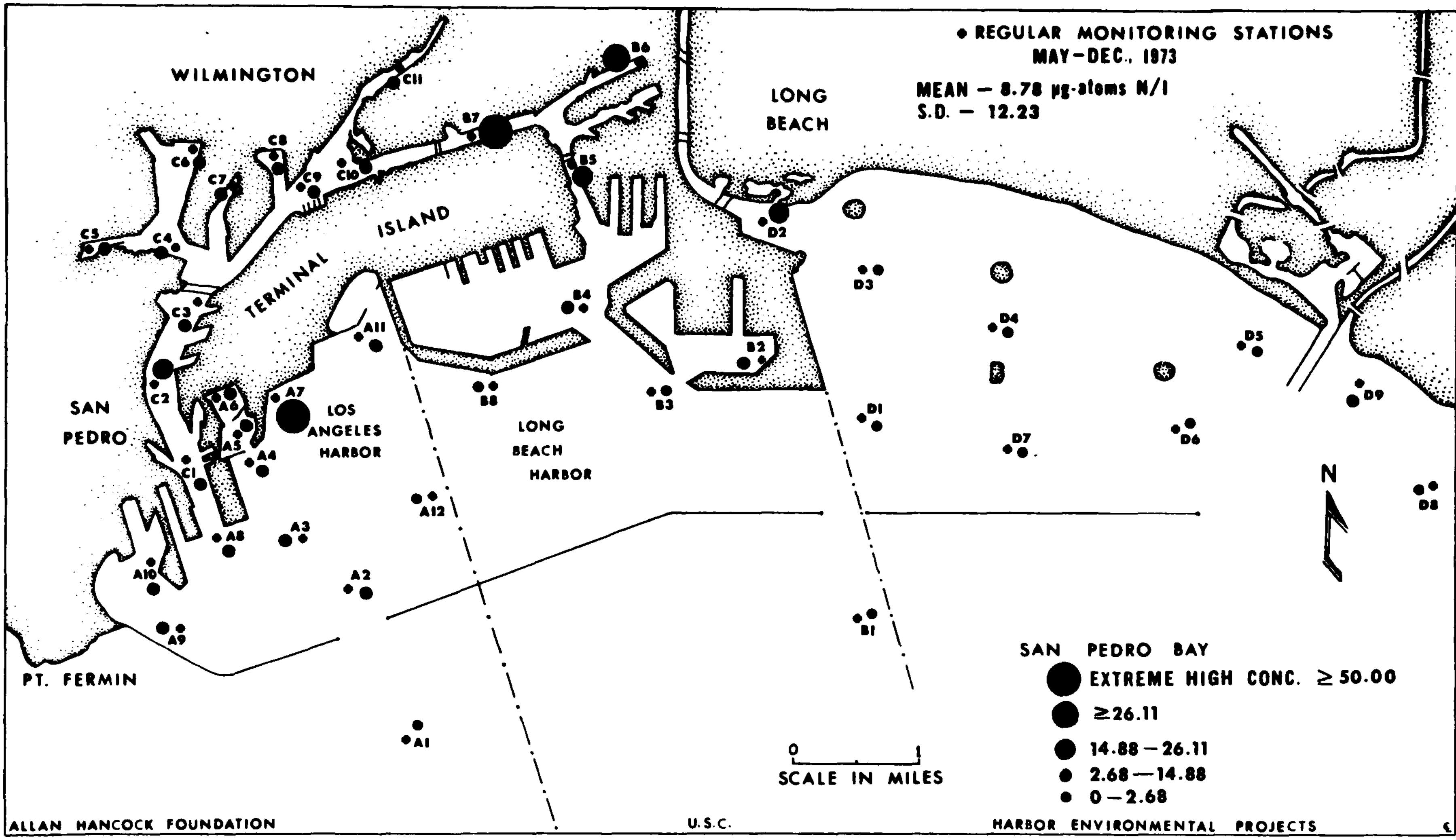


1973 NITRITE CONCENTRATIONS
Figure 10.4



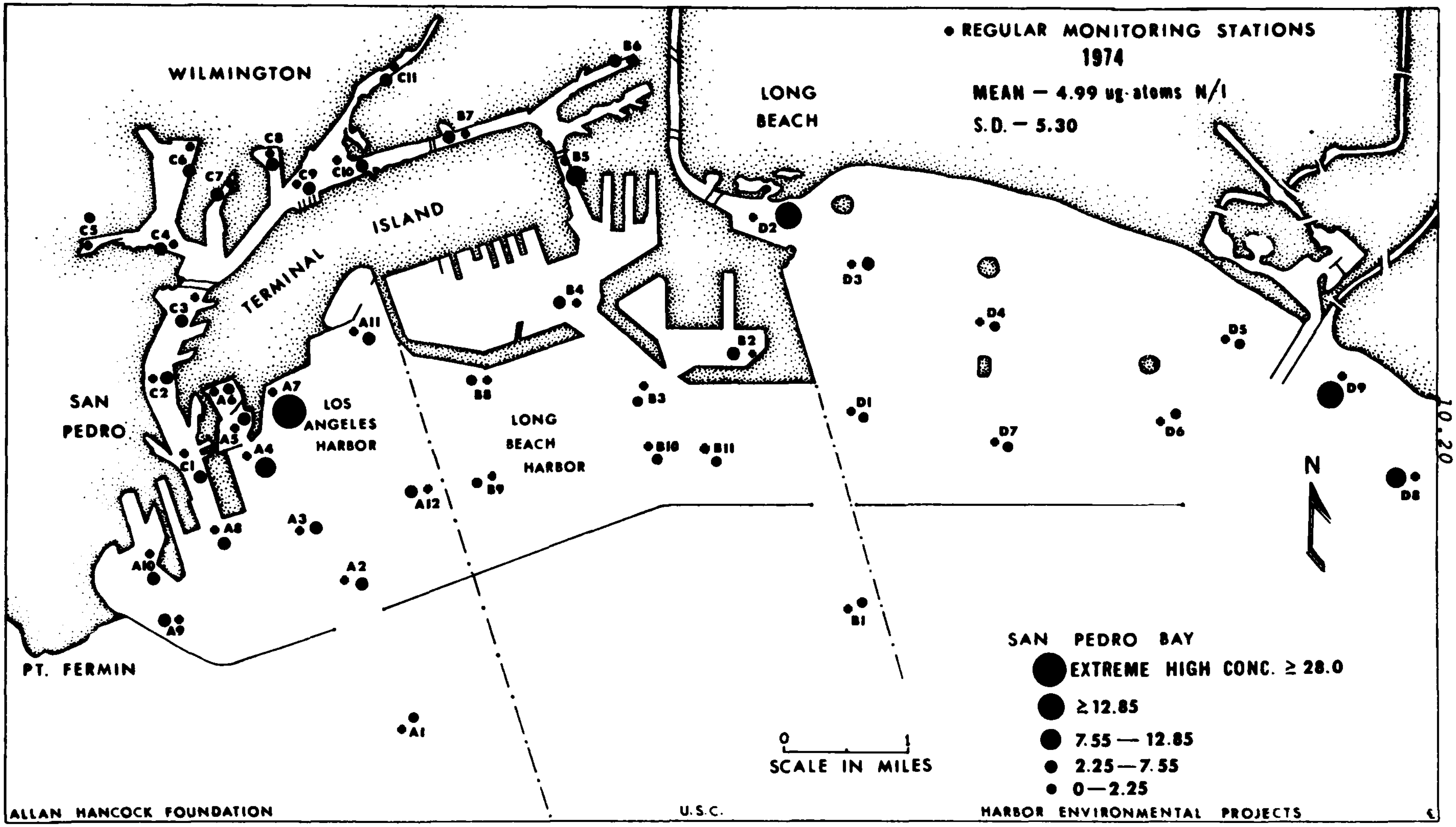
1974 NITRITE CONCENTRATIONS

Figure 10.5

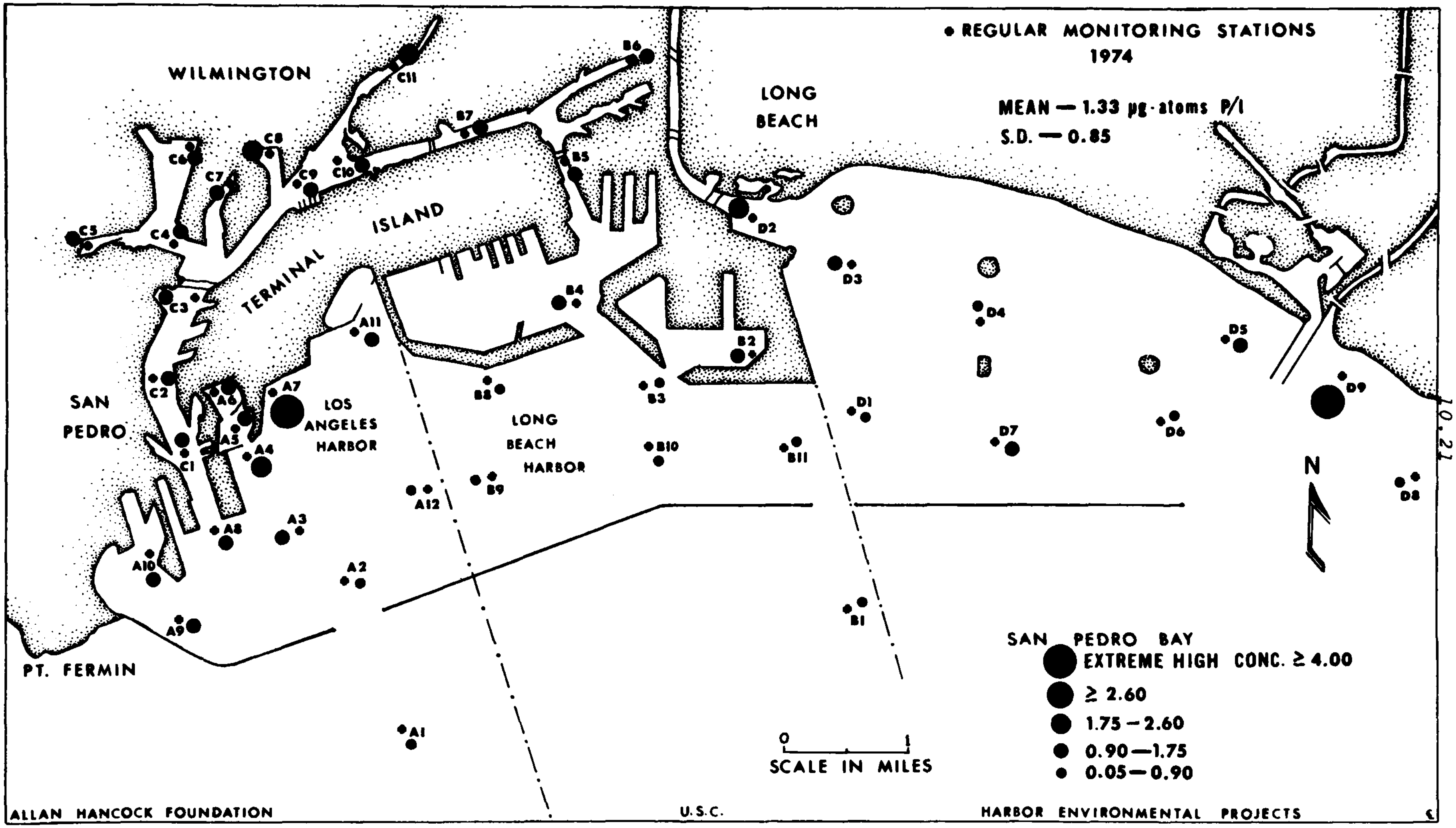


1973 AMMONIA CONCENTRATIONS

Figure 10.6



1974 AMMONIA CONCENTRATIONS
Figure 10.7



PHOSPHATE CONCENTRATIONS

Figure 10.8

Chapter 11

SEDIMENT DISTRIBUTION IN LOS ANGELES-LONG BEACH HARBORS

11.1

SEDIMENT DISTRIBUTION IN LOS ANGELES-LONG BEACH HARBORS

INTRODUCTION

The sedimentary regime of the Los Angeles Harbor area has been greatly modified by man. Dredging, filling, and the construction of the breakwater all affect the depositional characteristics of the area by modifying the energy patterns that affect the size and distribution of the sediment in the Harbor area. The dredged areas provide sediment traps that interrupt the flow of bed load sediments. Filled areas obstruct sediment movement, can cause deposition or erosion of areas adjacent to them, and may themselves be a source of sediments. The breakwater reduces the amount of energy available to transport sediment. This means that the area will have finer sediment than would otherwise be the case.

Distribution of sediments are one factor in the distribution of benthic organisms. Thus, a change in the distribution of sediments may be expected to cause a corresponding shift in benthic populations, all other factors remaining equal.

There is little previous work on sediment distribution in the Los Angeles/Long Beach Harbors. This makes it difficult to assess what is occurring to sediments. Sedimentary processes are, with some notable exceptions, generally slow. Response to a change in environmental conditions may not be clearly recognizable for thousands of years.

In this study, data from 34 stations in the Los Angeles Harbor area were analyzed in detail, with each station having at least one value, and some with as many as six values determined. See Figure 11.1 for location of stations.

METHODS AND MATERIALS

The samples that were analyzed for grain size were collected with a modified Reinecke box corer. The samples were collected from the top 2 cm. of the core, placed in a plastic container and frozen (for possible future chemical analysis). Prior to analysis, each sample was thawed, stirred thoroughly, and a split was taken, varying in size depending on sand content. The original sample was then re-frozen for archiving. Hydrogen peroxide (30%) was added to the sample to remove organic material. The samples were then washed three times with tap water and three times with distilled water to remove any trace of salt. The samples were then wet-screened through a 62 μ screen. The material that passed through the 62 μ screen was collected in a 1000 ml graduated cylinder.

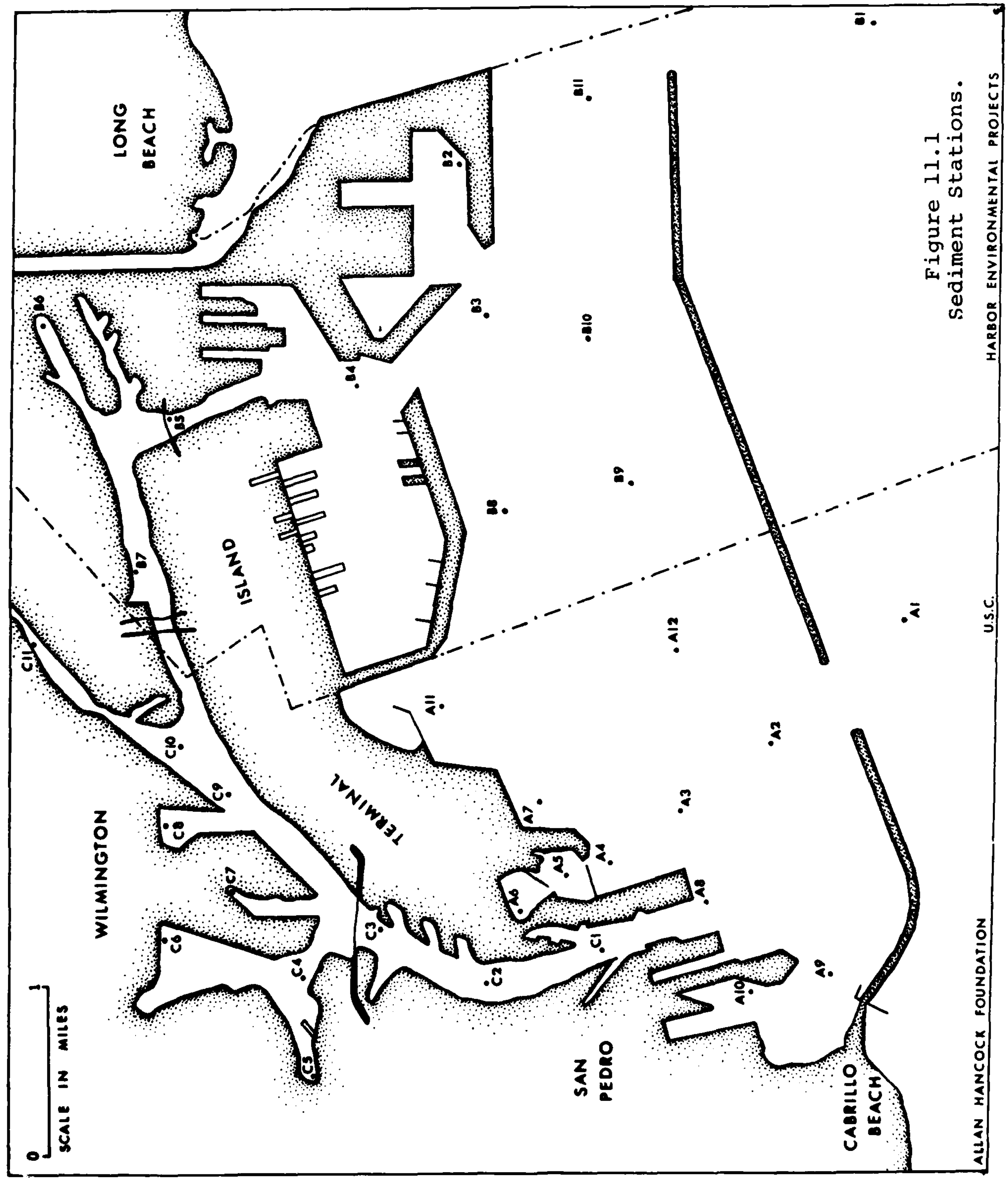


Figure 11.1
Sediment Stations.

The material that was retained on the screen was collected in a 50 ml beaker and dried. When this material was dried it was re-screened through a dry 62 μ screen, because a hydraulic factor causes some material that should have gone through the wet screen to be retained. The material that passes through on dry screening is added to the cylinder, and the remainder is weighed to a tenth of a milligram. A defloculent (0.3 ml of 20% NH_4OH) is added to the cylinder and the contents were analyzed by the standard pipette method (Pettijohn, 1957).

The coarse fraction (62 μ) was analyzed by a settling tube as described by Felix (1969) and calibrated according to Gibbs (1971). The coarse fraction (down to 4ø) was analyzed to ¼ø while the pipette fraction (down to 9.5ø) was analyzed at full ø intervals.

SORTING

Sorting is the result of a complex interaction between the sediment grains and the transporting medium. Flat or light mineral grains are favored in sediment moved by suspension, while heavier or spherical grains are favored in movement by traction. This difference in transport leads to selective sorting of the sediment grains. Sorting is also dependent on the constancy of the energy at the site of deposition. In general, if the energy level is fairly constant in a given area, then good sorting will result, while large fluctuations in energy levels will result in poor sorting. Finally, sorting is dependent on the source area of the sediment. That is, if the area of erosion is well sorted, then the sediment derived from that area will be well-sorted. This is generally true only near the site of erosion.

The measure of sorting used in this study was the Sharp and Fan Sorting Index (Sharp and Fan, 1963), with the modification that only the intervals analyzed (-0.5ø to 4ø at ¼ø intervals: 4-9.5ø at 1ø intervals) were used in the computations, rather than the standard 25ø intervals. This modification resulted in lowered sorting values. The index ranges from 100% (all the sediment in one size class) to 1% (the sediment distributed equally throughout all size classes). The Sharp and Fan Sorting Index was chosen because it takes into account any bi-modal aspect of the size distribution, something that other common measures of sorting do not do.

Sorting values for the Los Angeles Harbor are generally slightly lower than shelf sediments in the southern California area (Kolpack, pers. comm., 1975). Values for the shelf are commonly 25-35%, while most of the harbor area has values between 15 and 25%. The lower values in the harbor are most likely the result of the admixture of terrigenous clay, deposited because of the reduced wave and current energy in the harbor area. See Figures 11.2-11.6 for sorting values.

Areas of higher sorting include the entrance to the seaplane anchorage (A11), the southwest slip of Los Angeles Harbor (C5), the Cerritos Channel about 1200 feet east of the Heim lift bridge (B7), and the southeast basin of Long Beach Harbor (B2)(see Figure 11.1).

The entrance to the seaplane anchorage is a shallow area that is exposed to wave action. This action may result in the removal of some of the clays which would increase the sorting (Figures 11.7 through 11.11 for percent Clay). The values in the anchorage area are lower than those in nearby areas. The southwest slip receives runoff from a large storm drain located at its extreme west end. This runoff can be a source of sediment, and the currents resulting from the runoff may be responsible for the higher sorting values in this area.

The third area of high sorting is in the Cerritos Channel east of the lift bridge. It appears that the area is a node in the tidal currents (U.S. Army Corps of Engineers WES Model photographs), which is an area of back and forth rocking motion of the water. This rocking motion results in a "bean spreading" type of sorting in which the fines are moved out of the area. This explanation is reinforced by the percentage of sand which is high east of the bridge and decreased in both directions in May, 1974 (Figure 11.9).

The final area of high sorting is the Southeast Basin of Long Beach Harbor. This high does not lend itself to ready explanation. It is possible that it is the result of dredging for the construction of Pier J. Surge has been a recurrent problem in that area.

There are some apparent discrepancies in the data. The major one is the apparent reversal of the sorting pattern in the outer harbor between November, 1973 and November, 1974. It is highly unlikely that the sorting in fact changed to such an extent. It is more likely that this difference is caused by an accident of sampling. This accident could have been the result of washing of the sample as it was taken, which would remove some of the fines. It is also possible that one sample was taken on a small topographic high which was swept clean of fines, and a second sample was taken in a small depression where fine would collect. This type of problem can only be dealt with by analyzing a larger number of samples in a limited area, which would result in a sounder basis for interpretation.

Textural maturity is dependent on the percentage of clay, the sorting, and the roundness of a sediment. Since all the areas in the harbor have more than a 5% admixture of clay, the sediments are classified as immature (Folk, 1968).

PERCENT SAND, SILT AND CLAY

The definitions used in plotting the percentages of sand, silt and clay follow the accepted Phi scale:

Grain Type	Grain Size	Millimeters
Sand	4ø	> 0.0625
Silt	4ø-8ø	0.0625-0.0039
Clay	8ø	< 0.0039

Under the Phi scale, rising ø values indicate smaller sizes. Phi represents the logarithm of the diameter of the sediment grains.

The percentages of sand are shown in Figures 11.7-11.11, as sampled in March and November of 1973, and May and November of 1974. Considerable variation was found, which may indicate instability, or differences in sampling location.

The percentages of silt for the various sampling dates are shown in Figures 11.12-11.16 and percentages of clay are presented in Figures 11.17-11.21.

MEAN GRAIN SIZE

The mean grain size of sediments is dependent on several factors. The first is the size of available material, and the second is the amount of energy available to transport this material. In general, the higher the energy, the larger the grains that can be moved. The energy for transport in the case of marine sediments comes from wave action, currents, and turbulence of the water. Topography also plays a part in the distribution and size of sediments. Coarser sediment will be deposited in topographic highs than will be deposited in topographic lows. See Figures 11.22-11.26 for Grain Size.

Wave energy becomes available to transport sediment when the wave begins to feel bottom, and more energy is released when the wave breaks. Wave energy tends to be concentrated on points of land and dispersed along broad areas. Where wave energy is concentrated, you would expect to find coarser sediments. This may explain the coarse sediment found just east of Reservation Point.

Breakwaters, moles, dredged channels, etc., all affect the distribution of wave energy, and hence have an effect on the distribution of sediments. In addition to affecting the energy distribution, the dredged channels act as sediment traps. The channels intercept any coarse particles that may be moved by traction along the bottom. This can be

seen as an increase in the mean size and the higher percentage of sand in the dredged channels of both Los Angeles and Long Beach Harbors.

The small mean diameter in the Watchorn Basin and the high silt values for this area may be the result of the source area of the sediments. The Timms Point silt outcrops (Kennedy, 1975) just to the northwest of the Watchorn Basin may supply a large amount of silt-sized particles to the area. Figures 11.12 through 11.16 illustrate the percentages of silt recorded. A curious decrease in mean grain size is found around the cannery and sewer outfalls (A7). This may be the result of coagulated protein either trapping fine sediment grains, or of fine sediment grains adhering to the surface of the protein and being carried to the bottom. Once on the bottom, the coagulated protein mass could keep waves and currents from removing the fine sediment. Dumping of dredge spoils and shoreline fill has also occurred in the area in recent years.

There are discrepancies similar to those in the sorting plots found in the mean diameter plots. The major discrepancy seems to be at station C2 in the main channel of Los Angeles Harbor. For two cruises (3/22/73 and 11/30/73) this area had a mean grain size of 0.02-3.0 mm, while for two other cruises (5/20/74 and 11/2/74) the values for this station are .11 mm and 0.09 mm. In looking at these discrepancies it must be remembered that the sedimentary environment has been modified over the years by dredging, filling and the construction of breakwaters. Sedimentary processes are generally slow and require time to come into equilibrium with a new set of conditions. Also, since the samples were taken at slightly different locations, some variation could be introduced in this way. However, if the area was in equilibrium it would be unusual to have such a large variation over a small distance. Maintenance dredging and construction carried out at Berth 231 could have affected the readings at C2; two major sewer line breaks also occurred in the area during the period of study.

Because of the wide variation shown by the 1973-1974 samples in Cerritos Channel and the upper main (back) channel at stations B5, B7 and C10, additional sampling was undertaken in 1976 for the Port of Long Beach. Fifty-one stations were sampled in the area from the Gerald Desmond Bridge (B5) to Channel Two and Channel Three (B6) and west to the Heim lift bridge (B7).

Figures 11.27-11.30 show the percentages of sand, silt and clay and levels of oil and grease found. Together these show that the deeper center portion of the channel contain the higher percentages of silt and clay, while the area along the banks of Terminal Island had the higher percentages of sand.

Pollutants often are adsorbed by the finer particles (silts and clays) and the higher concentrations of oil and grease followed those patterns. Fines tend to drift down into lower areas and hence accumulate in the center of the dredged channels, or in low spots and areas of poor circulation.

SEDIMENT POLLUTANTS

The physical characters of the sediments, such as grain size, determine the distribution of benthic species living in the sediments. The levels of pollutants which have accumulated in urban areas where industrial wastes are released also influences the species diversity and number extensively.

Smith (1973) related abiotic parameters including trace metals to the distribution patterns of benthic organisms in outer Los Angeles Harbor. Emerson (1974) studied the bioassay effects on two species of polychaete worms of resuspended sediments from inner Los Angeles Harbor at a proposed pipeline crossing in East Basin. Chen and Lu (1974) compared sediment pollutant levels at 42 stations in Los Angeles-Long Beach Harbors (see Chapter 12 herein), with levels in the Catalina Channel. Marine Studies of San Pedro Bay, California, Vol. 11 (1976) deals entirely with biological impacts of dredging, including toxicity of sediments containing trace metals and chlorinated hydrocarbons. In that volume Soule and Oguri, Brewer, Chamberlain, McConaugha, Emerson, Chen and Eichenberger, and Reish and King detailed various potential effects of dredging polluted sediments. Chen and Wang reviewed the changed EPA requirements for dredge spoil criteria, detailed results of elutriate tests, and summarized the sequestering and release of contaminants.

Figures 11.31-11.44 are appended to the present section as a subsection of computer maps generated from the Harbors Environmental Projects data bank by John W. McDonald. These show the relative mean concentrations of pollutant parameters in sediments throughout the harbors. On facing pages are the legends illustrating the symbols for various concentrations, the frequency of occurrences, and the ranges of the measurements.

IMPACT

If the filling of the outer harbor results in a decrease in circulation, then it is likely that finer sediment will accumulate. If the energy patterns are altered there is the possibility that present areas of erosion will become areas of deposition and vice versa.

Dredging the Los Angeles Harbor main channel would remove large amounts of silt-sand size range of particles from the bottom surface. The short term implications of dredging activity are of two sorts: those associated with physical resuspension of sediment and those associated with release or exchange of chemical pollutants due to resuspension.

The first relates to creation of siltation and turbidity in the water column, which can cause smothering of those benthic animals directly in the rain of suspended sediment. Or asphixiation of filter feeding organisms may occur in adjacent areas when respiratory surfaces become clogged. Turbidity may decrease light transmittance sufficiently to inhibit phytoplankton growth, and hence interrupt the zooplankton food source. The season in which dredging occurs makes a difference in organisms potentially affected, since zooplankton reproductive peaks are associated with particular preferred phytoplankton food source.

Recolonization studies indicate that the sediments that settle out of disturbed waters are sufficient to furnish substrate for new benthic larvae within 4-8 months, in areas where fine precipitates would form reasonably stable surfaces.

The effects of resuspension of pollutants complexed with sediments are discussed in detail in Chapter 12. It is likely that anoxic subsurface bottom sediments will cause a large oxygen demand upon release in the water column, either during dredging or disposal. This will probably result in depletion of dissolved oxygen within harbor confines, which may affect sessile organisms and some fishes. Since birds and fish are attracted to dredging areas to feed, some uptake of pollutants may occur in the food chain and may result in unusually high levels of trace metals in the fish.

Disposal at sea will have less impact on oxygen depletion, but will distribute pollutants in the water column downstream of the actual dumpsite.

Long term implications relate to changes in the average grain size distribution and circulation patterns. The finest particles will remain for some time in the water column, and will settle over the coarser sediments exposed by dredging. If the fill patterns result in significant reduction of circulation, such as would occur under the extensive master plan, deposition of silts will be increased.

The extensive alteration of land configurations could lead to erosion of adjacent coastal beaches and shorelines. There is not data base on localized circulation on which to predict coastal impacts outside the harbor.

LITERATURE CITED

Brewer, G.D. 1976. Resuspended sediment elutriate studies on the northern anchovy. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 11. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 15-32.

Chamberlain, D.W. 1976. Effects of Los Angeles Harbor sediment elutriate on the California killifish, *Fundulus parvipinnis*, and white croaker, *Genyonemus lineatus*. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 11. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 33-48.

Chen, K. and B.Eichenberger. 1976. Concentrations of trace elements and chlorinated hydrocarbons in marine fish. Appendix II. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 11. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles.

Chen, K. and J.C.S.Lu. 1974. Sediment compositions in Los Angeles-Long Beach Harbors and San Pedro Basin. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 7. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 1-177.

Chen, K. and C.C.Wang. 1976. Water quality evaluation of dredged material disposal from Los Angeles Harbor. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 11. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 155-236.

Emerson, R.R. 1974. Preliminary investigations of the effects of resuspended sediment on two species of benthic polychaetes from Los Angeles Harbor. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 3. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 97-110.

Emerson, R.R. 1976. Bioassay and heavy metal uptake investigations of resuspended sediment on two species of polychaetous annelids. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 11. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 69-90.

Felix, D.W. 1969. An inexpensive recording settling tube for analysis of sands. J. Sed. Petrol. 39(2):777-780.

Folk, R.L. 1968. Petrology of sedimentary rocks. Univ. Texas.

Gibbs, R.J., M.P.Matthews, and D.A.Link. 1971. The relationship between sphere size and settling velocity. J.Sed. Petrol. 41(1):7-18.

Kennedy, G. 1975. Paleontologic record of areas adjacent to the Los Angeles and Long Beach Harbors, Los Angeles County, California. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 9. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. 119 p.

McConaugha, J.R. 1976. Toxicity and heavy metals in three species of crustacea from Los Angeles Harbor sediments. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 11. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 49-68.

Pettijohn, F.J. 1957. Sedimentary rocks. 2nd ed. Harper and Row, New York, Evanston and London.

Smith, R.W. 1973. Numerical analysis of a benthic transect in the vicinity of waste discharges in outer Los Angeles Harbor. In Marine Studies of San Pedro Bay, California. D. Soule and M.Oguri, eds. Part II, Biological Investigations. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 193-237.

Soule, D.F. and M.Oguri. 1976. Potential ecological effects of hydraulic dredging in Los Angeles Harbor: An overview. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 11. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 1-14.

Reish, D.J. and K.King. 1976. Concentrations of trace metals in marine organisms. Appendix III. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 11. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles.

Sharp, W.E. and P.F.Fan. 1963. A sorting index. J. Geol. 71: 76-83.

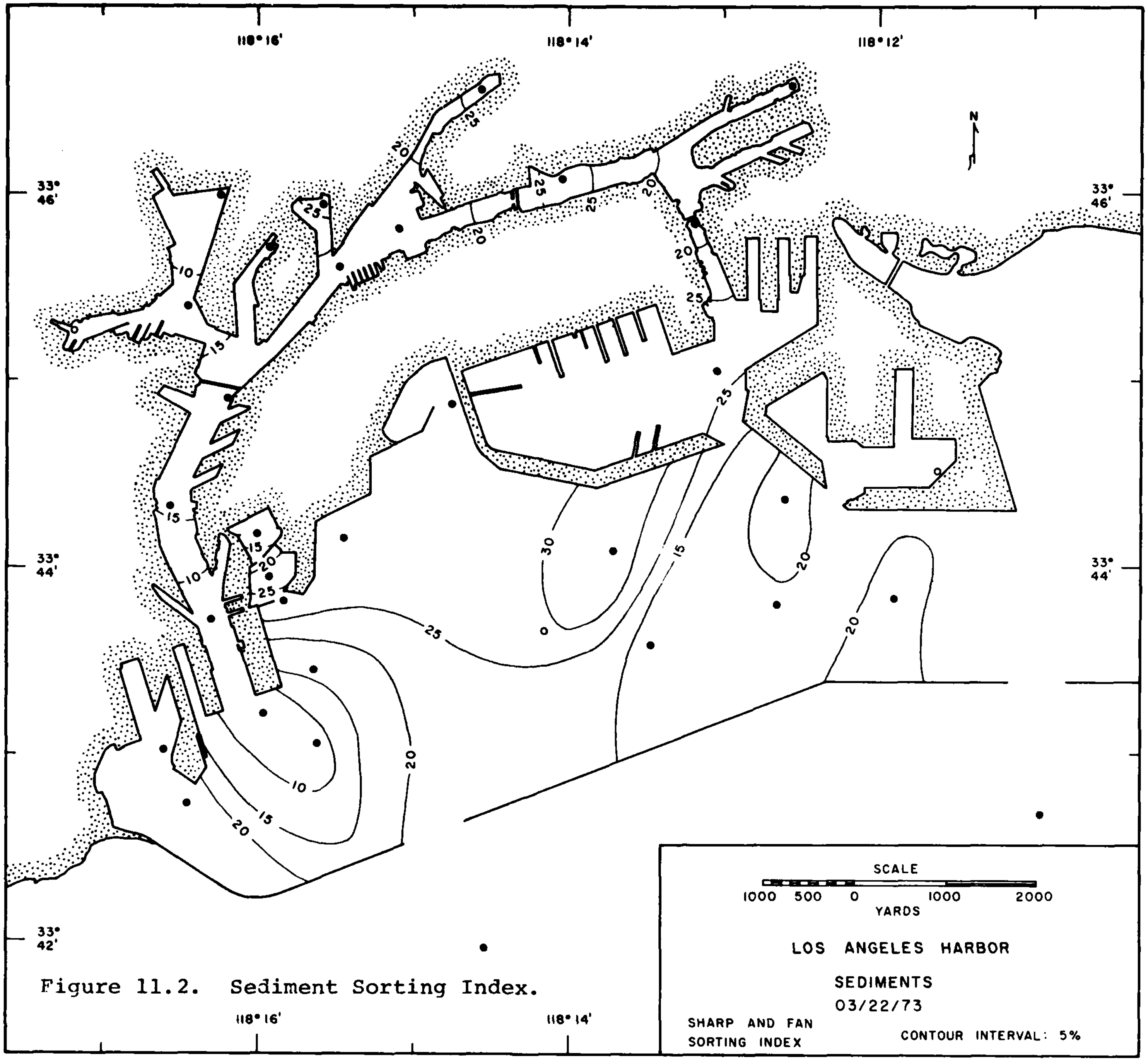


Figure 11.2. Sediment Sorting Index.

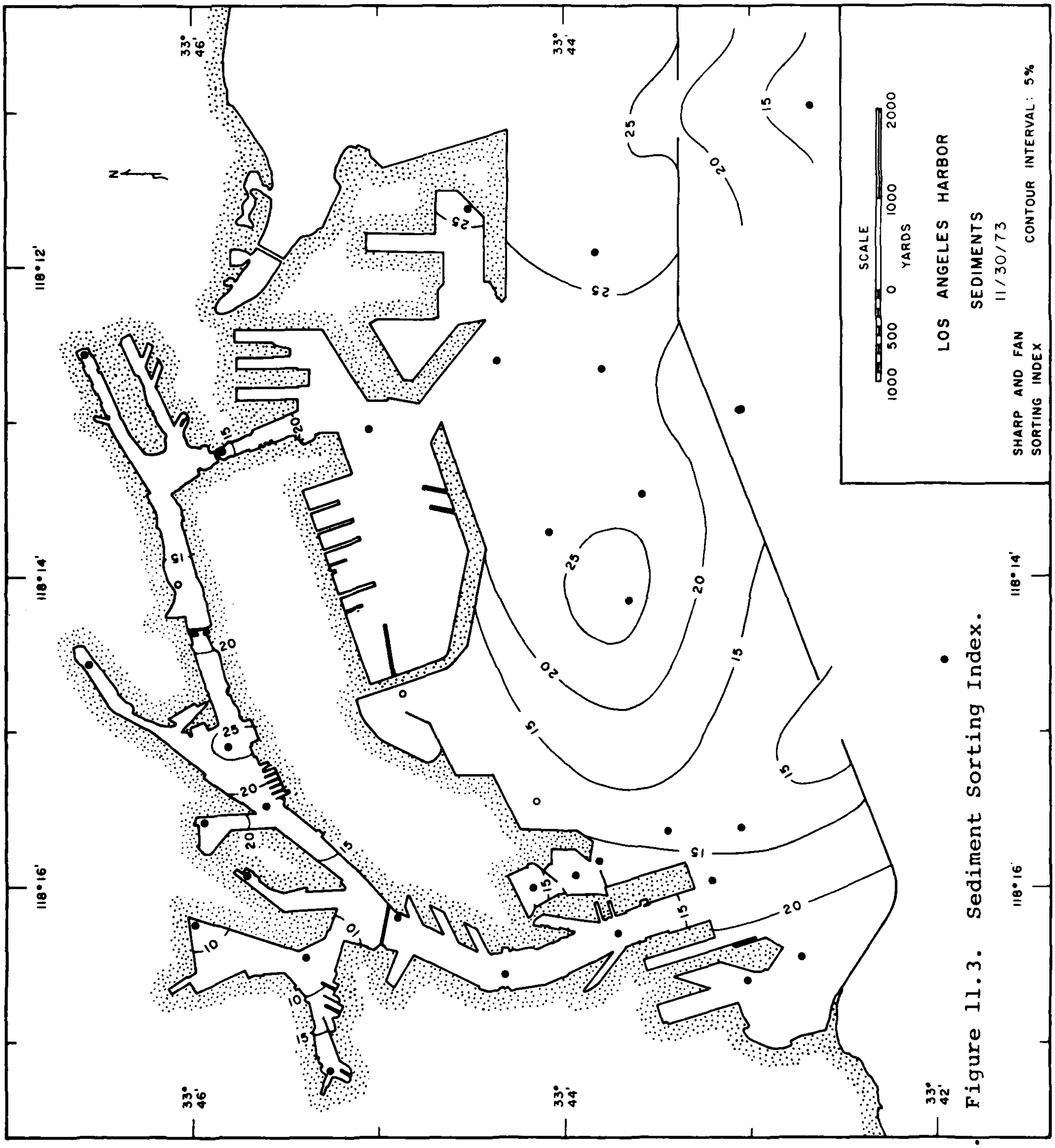


Figure 11.3. Sediment Sorting Index.

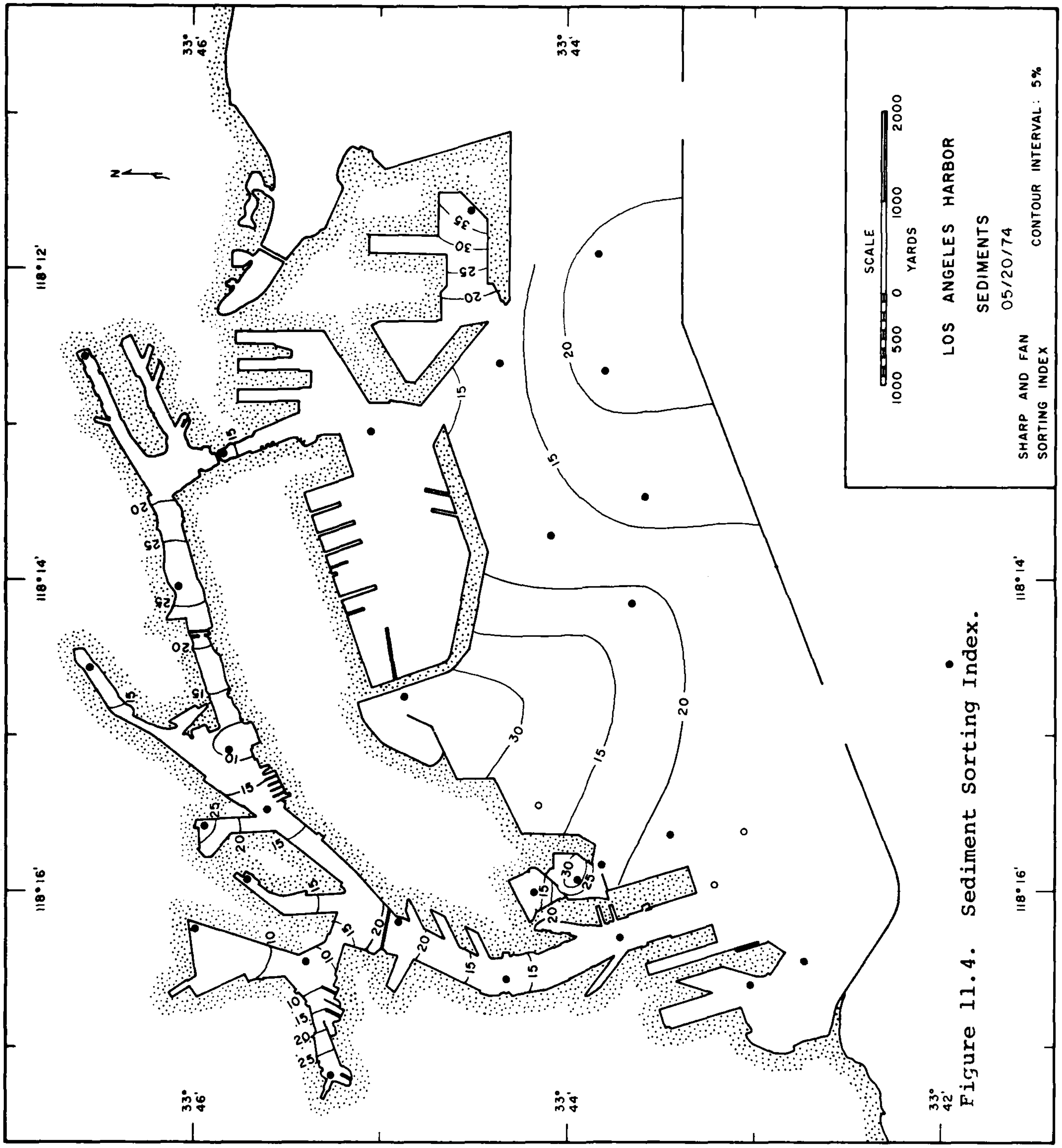


Figure 11.4. Sediment Sorting Index.

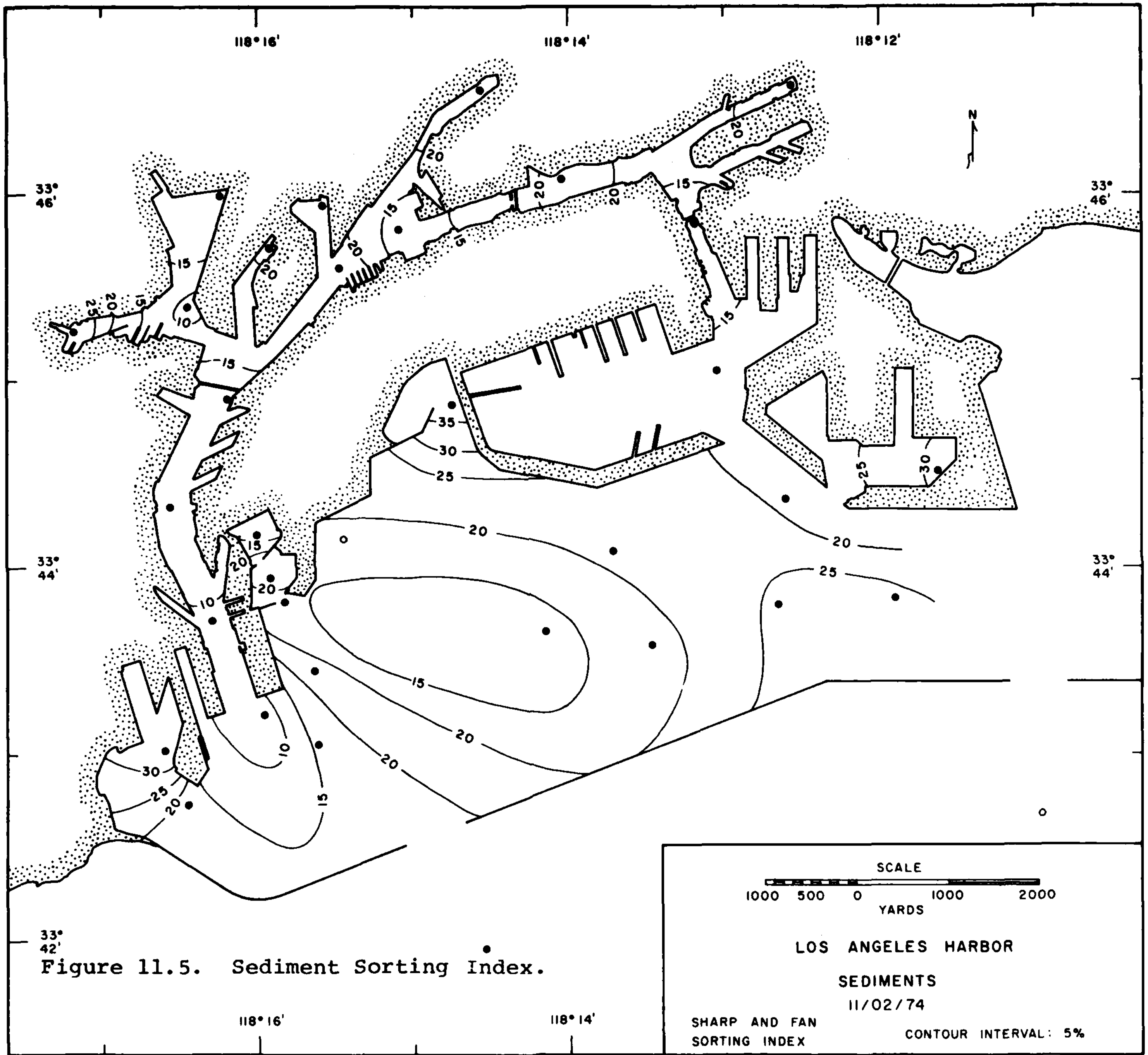


Figure 11.5. Sediment Sorting Index.

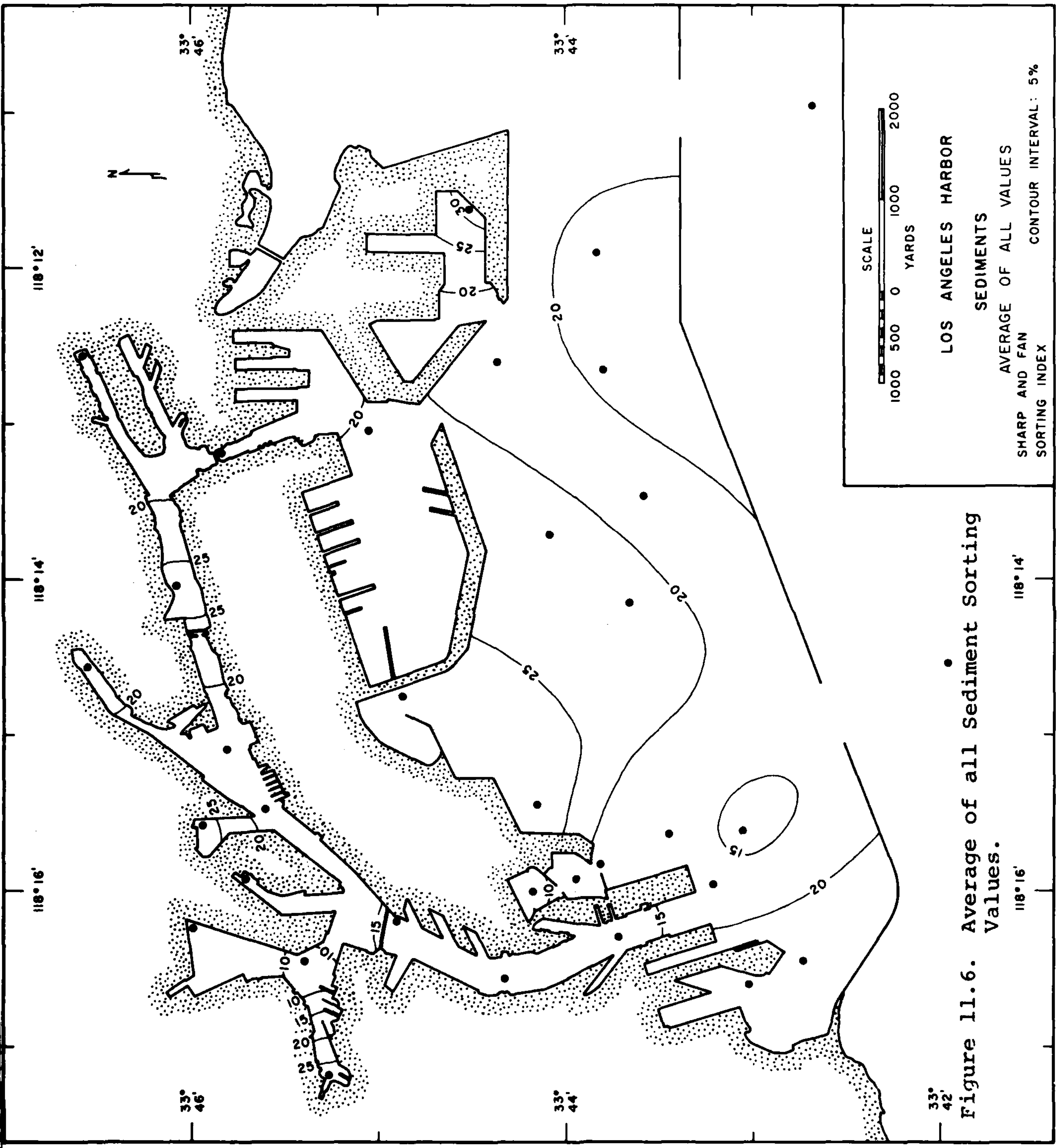


Figure 11.6. Average of all Sediment Sorting Values.

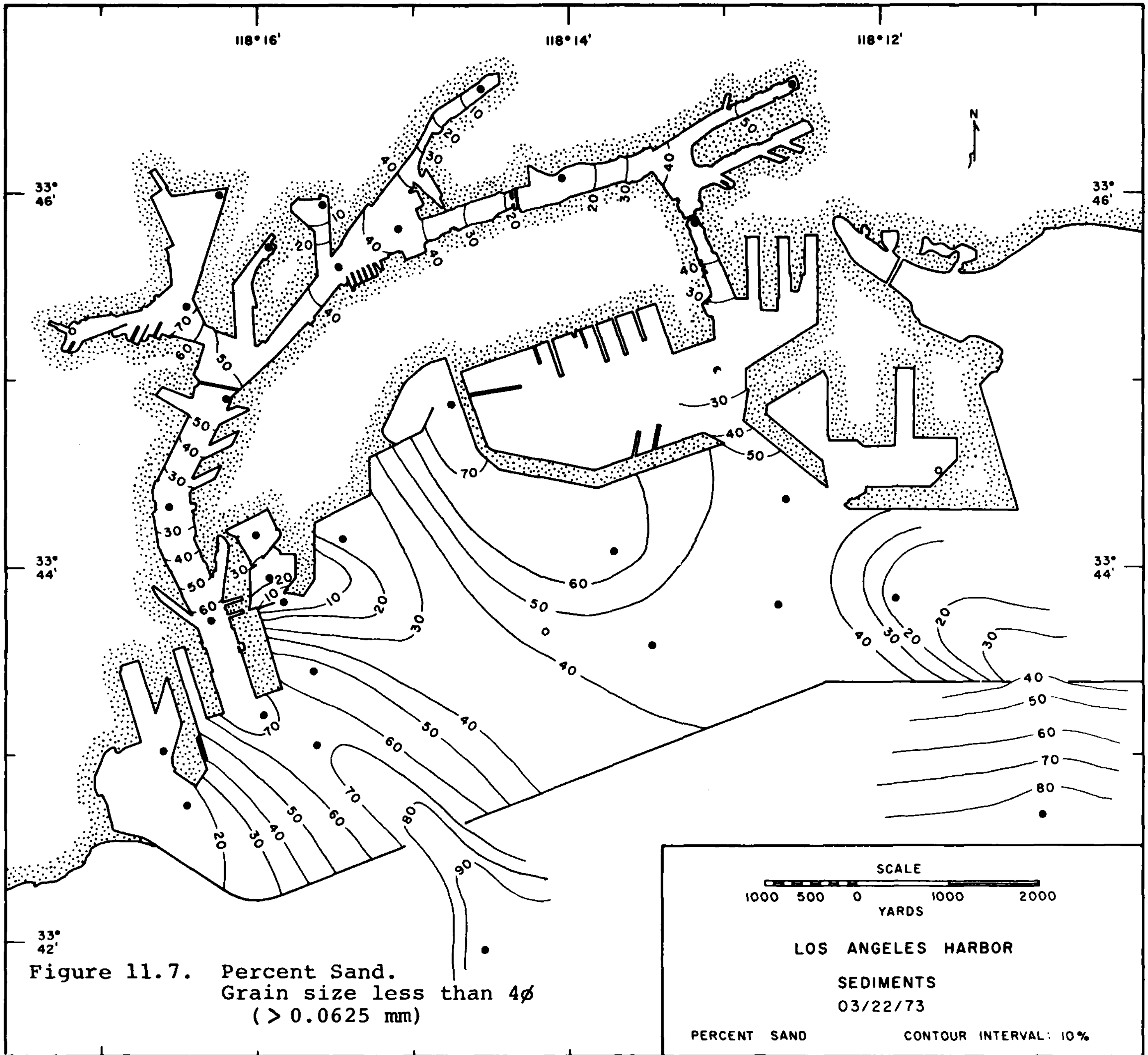


Figure 11.7. Percent Sand.
Grain size less than 4ø
(> 0.0625 mm)

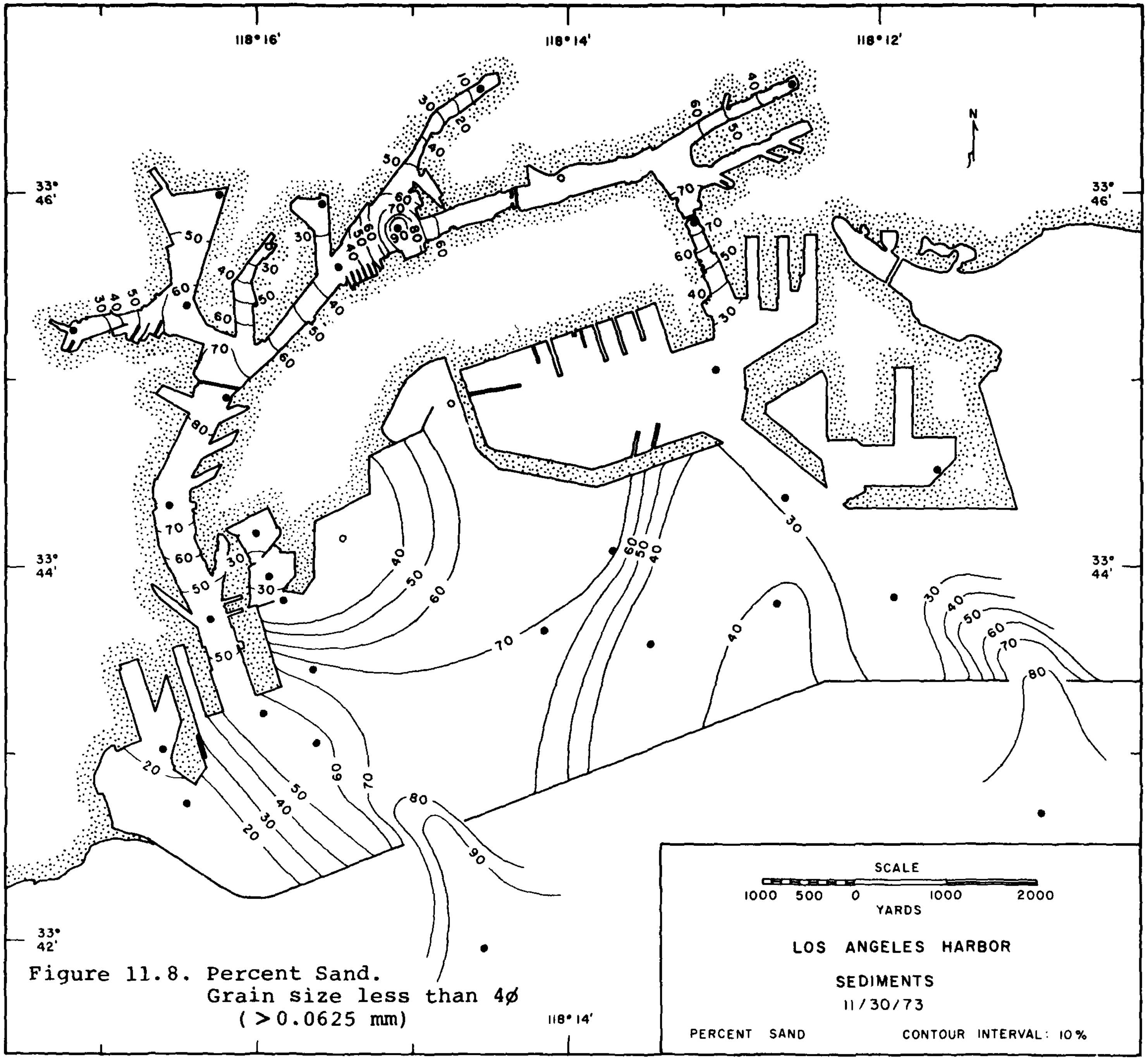


Figure 11.8. Percent Sand.
Grain size less than 4ø
(>0.0625 mm)

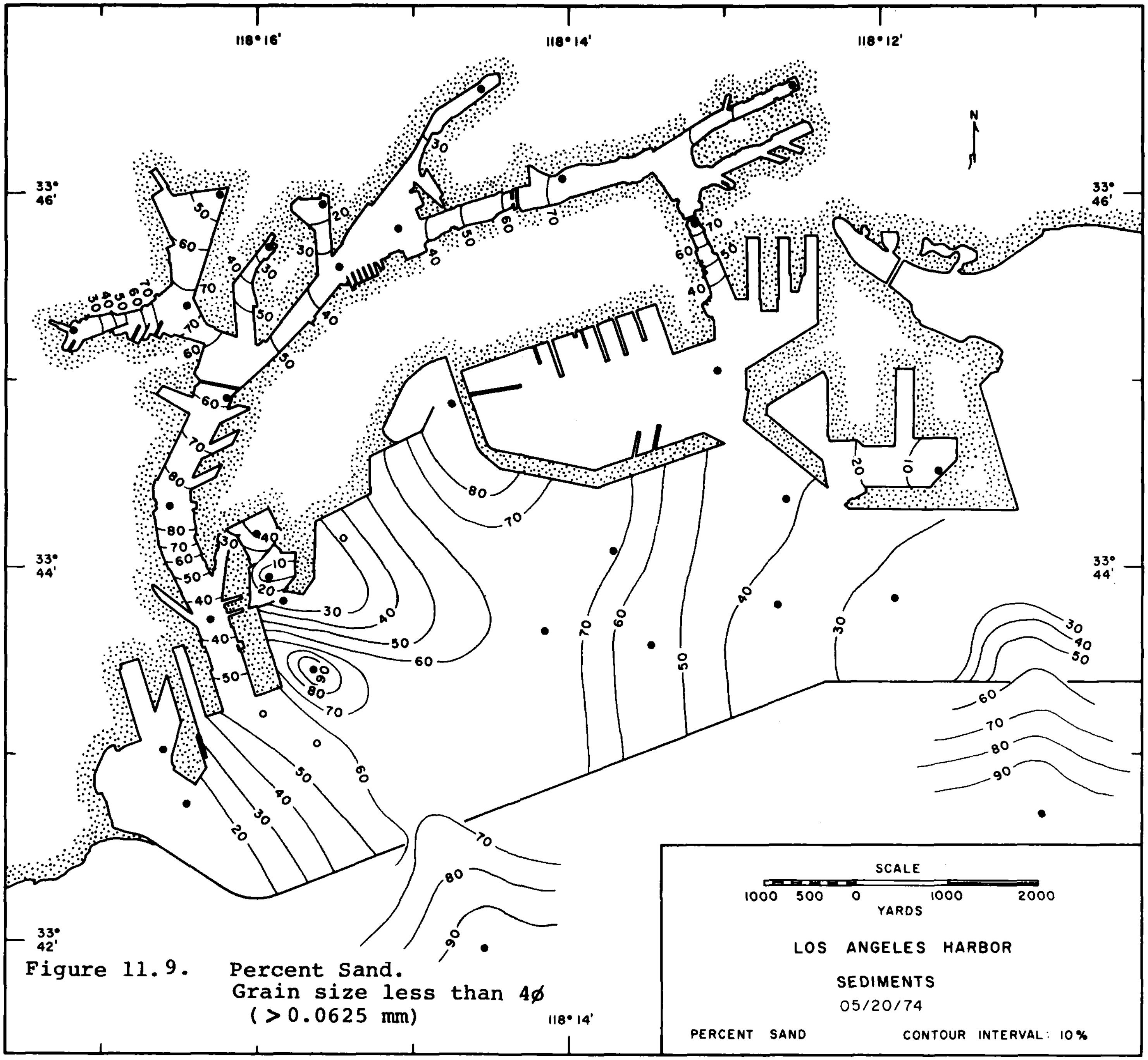


Figure 11.9. Percent Sand.
Grain size less than 4ø
(> 0.0625 mm)

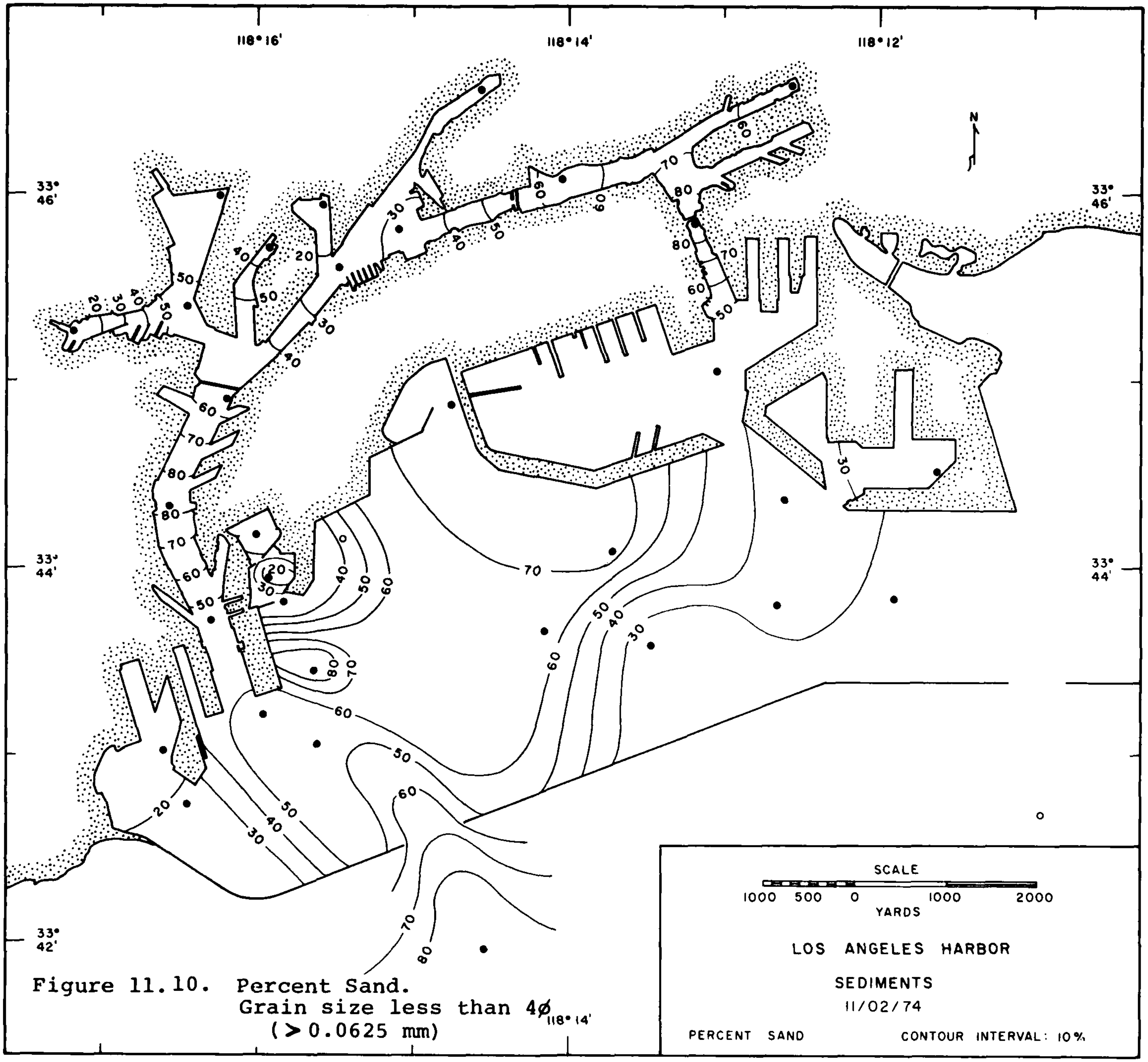


Figure 11.10. Percent Sand.
Grain size less than 4ø
(> 0.0625 mm)

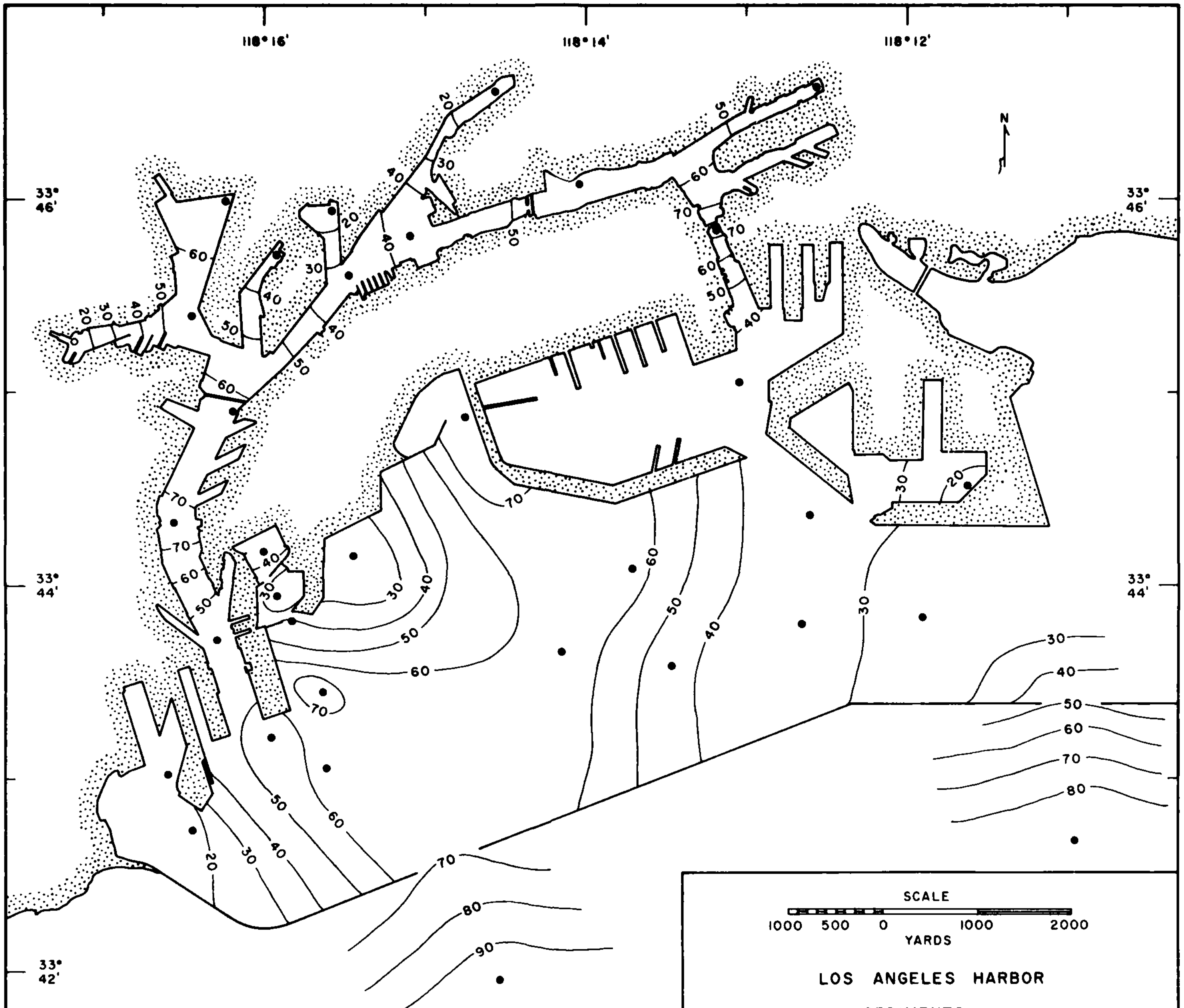


Figure 11.11. Averages of Percent Sand. Grain size less than 4ø (> 0.0625 mm)

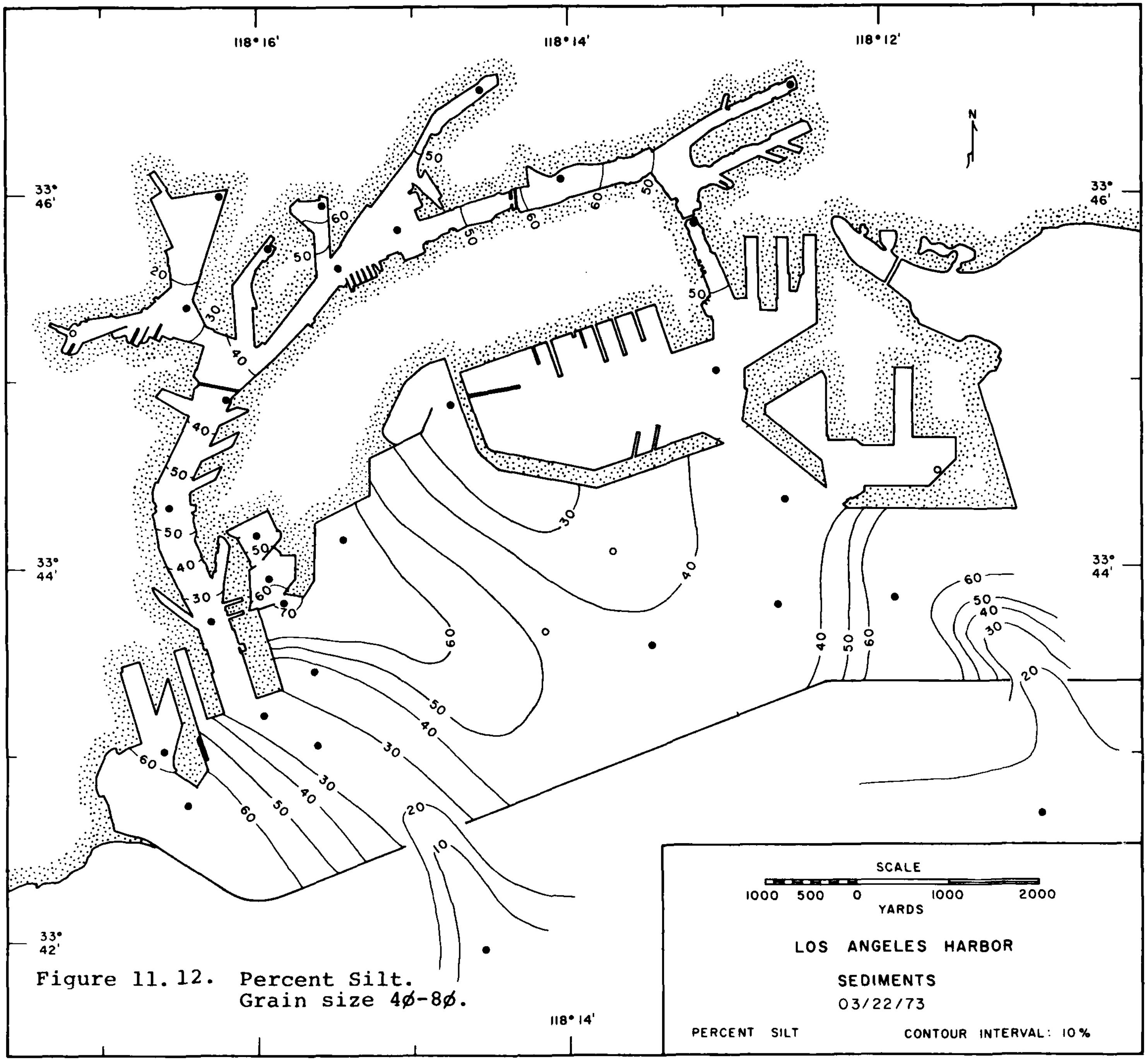


Figure 11.12. Percent Silt.
Grain size 4ϕ-8ϕ.

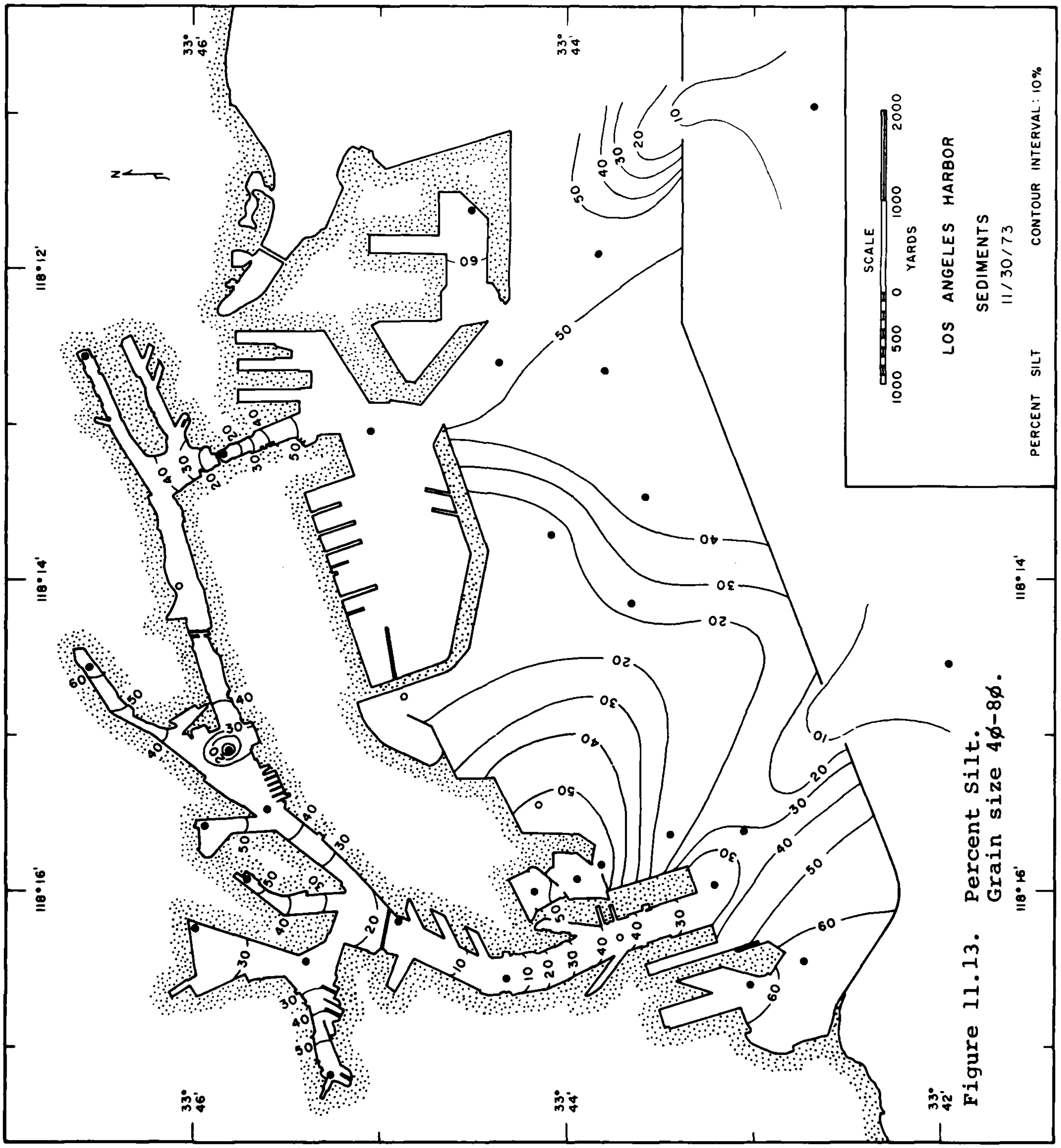


Figure 11.13. Percent Silt.
Grain size 4ø-8ø.

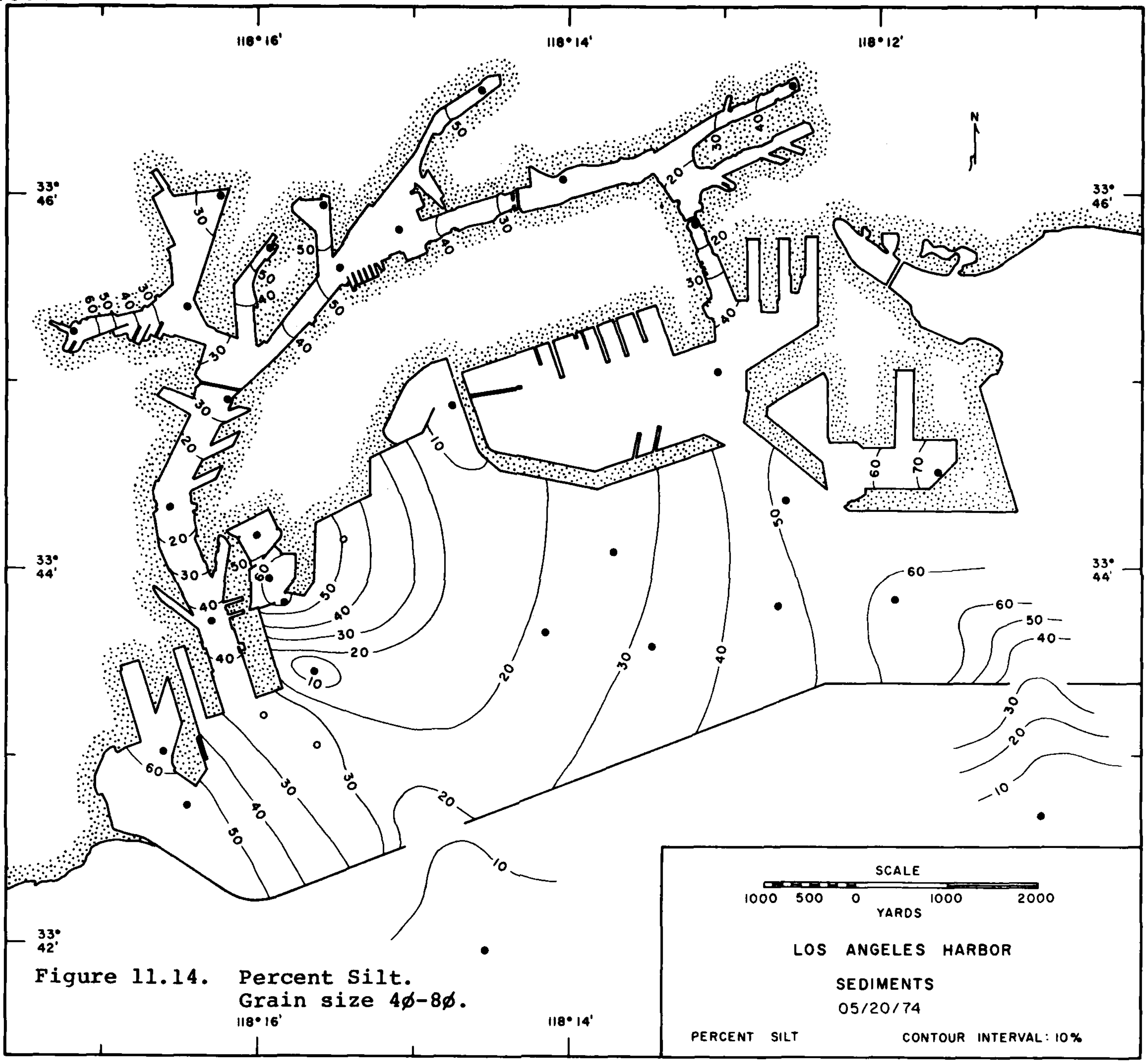


Figure 11.14. Percent Silt.
Grain size 4ø-8ø.

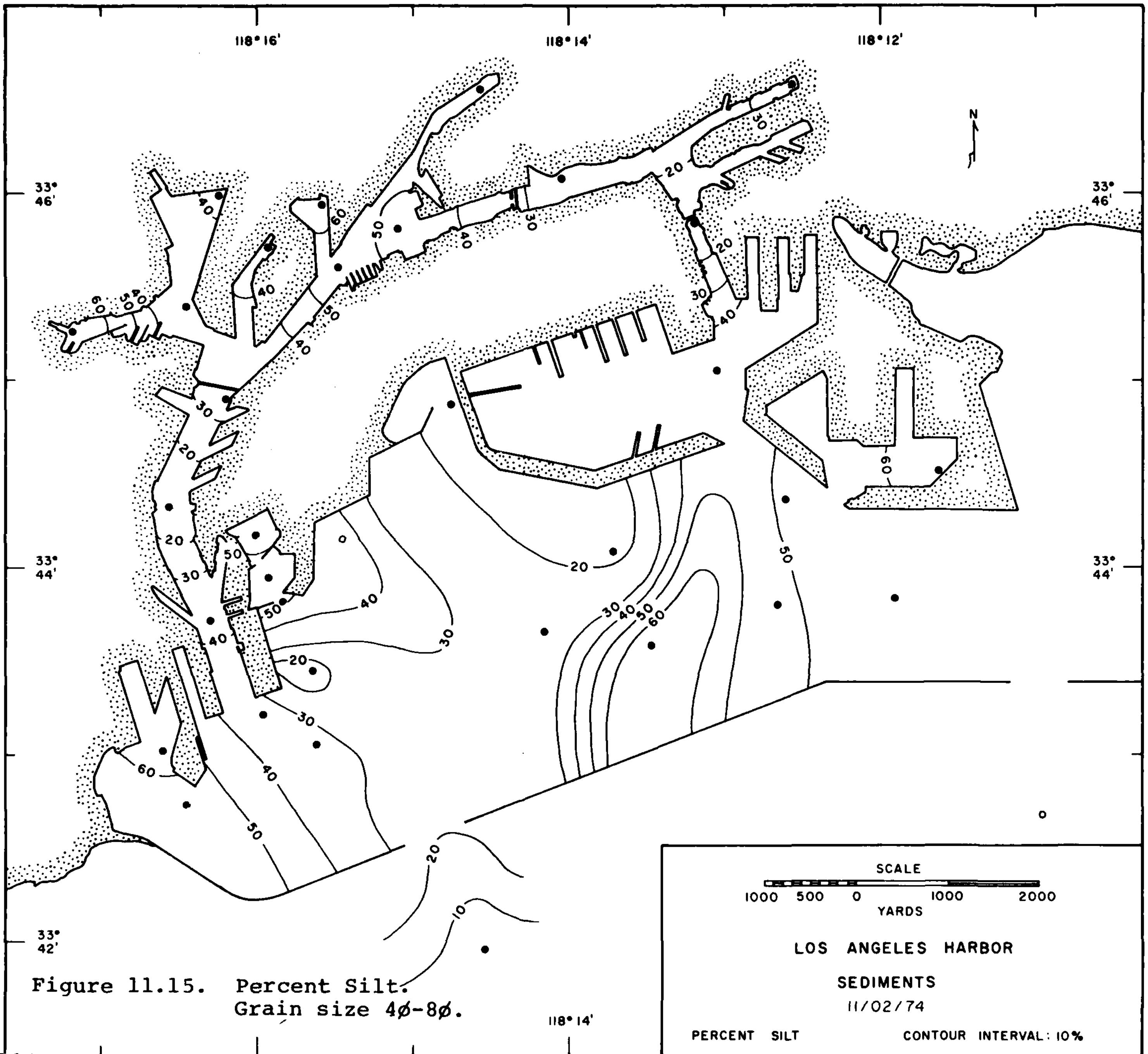


Figure 11.15. Percent Silt.
Grain size 4ø-8ø.

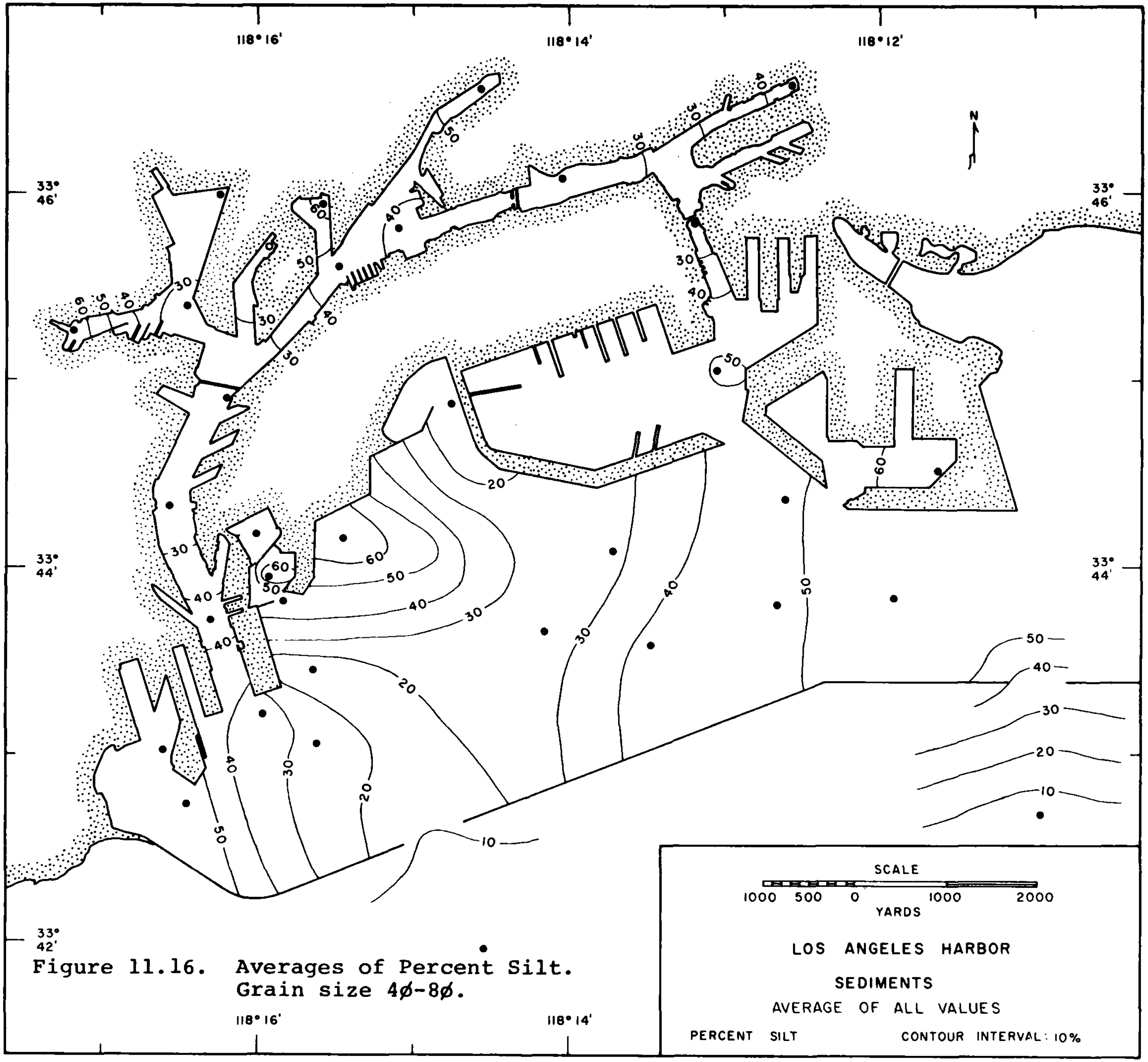


Figure 11.16. Averages of Percent Silt.
Grain size 4ø-8ø.

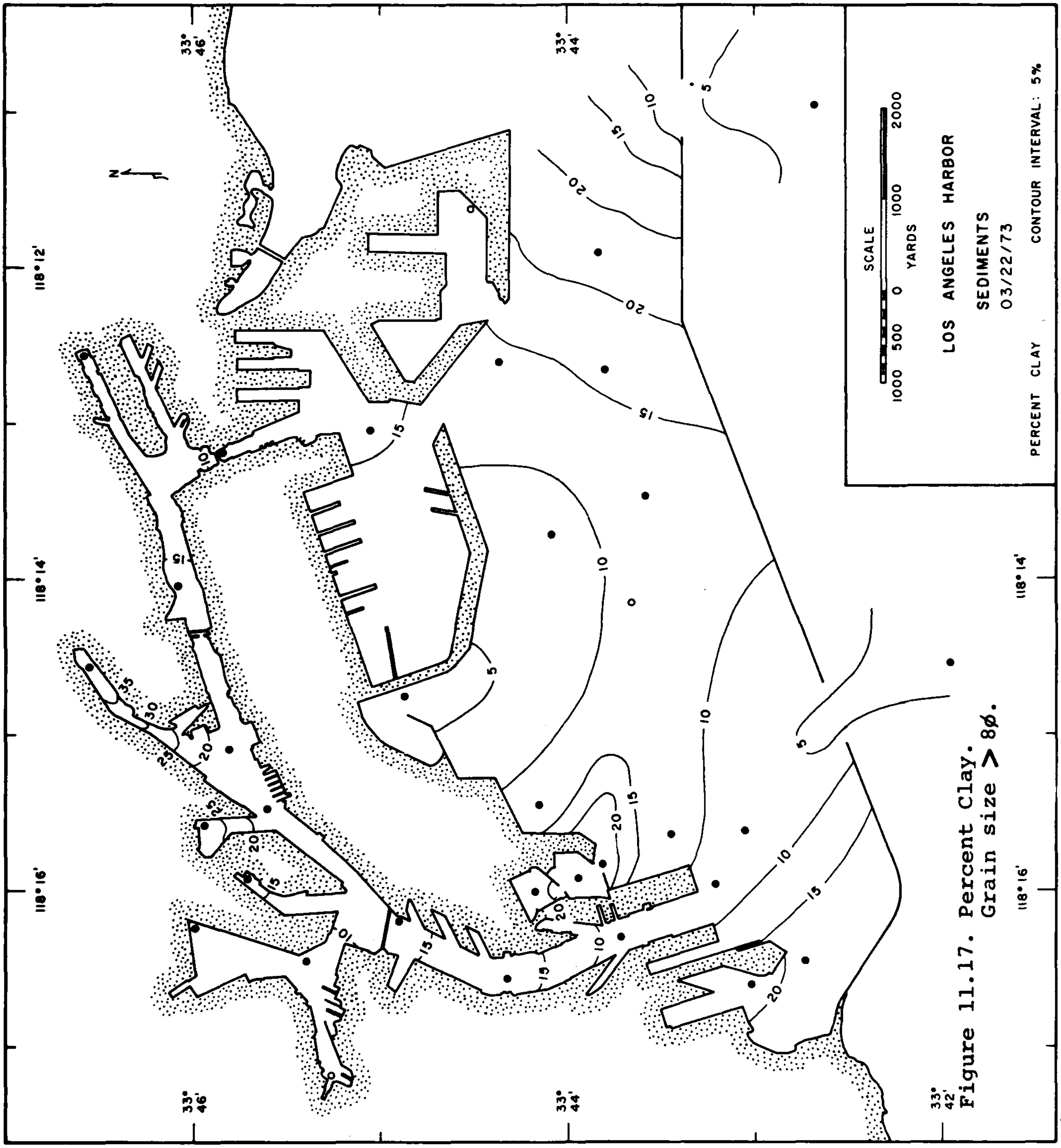


Figure 11.17. Percent Clay.
Grain size > 8ϕ.

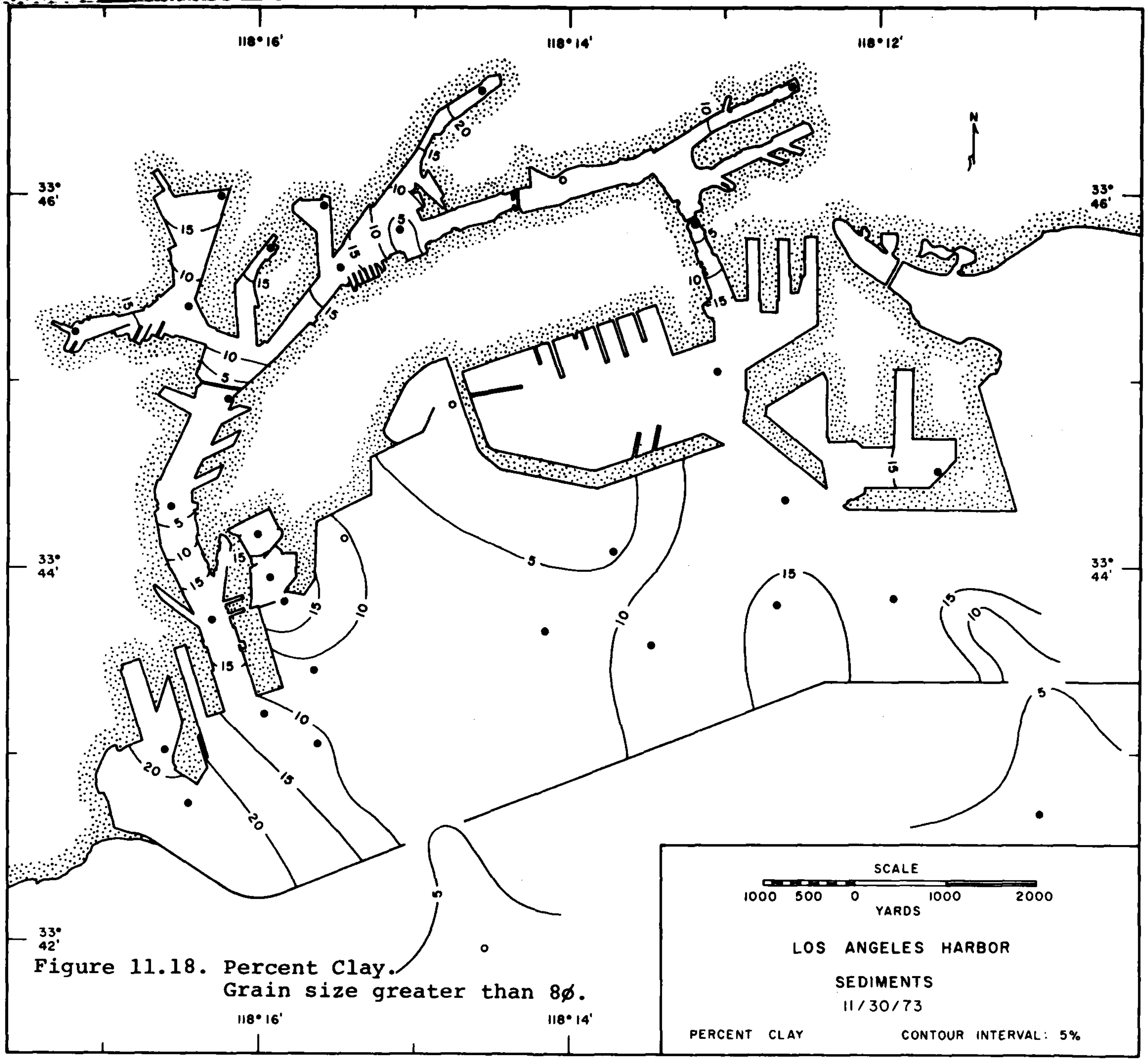


Figure 11.18. Percent Clay.
Grain size greater than 8ø.

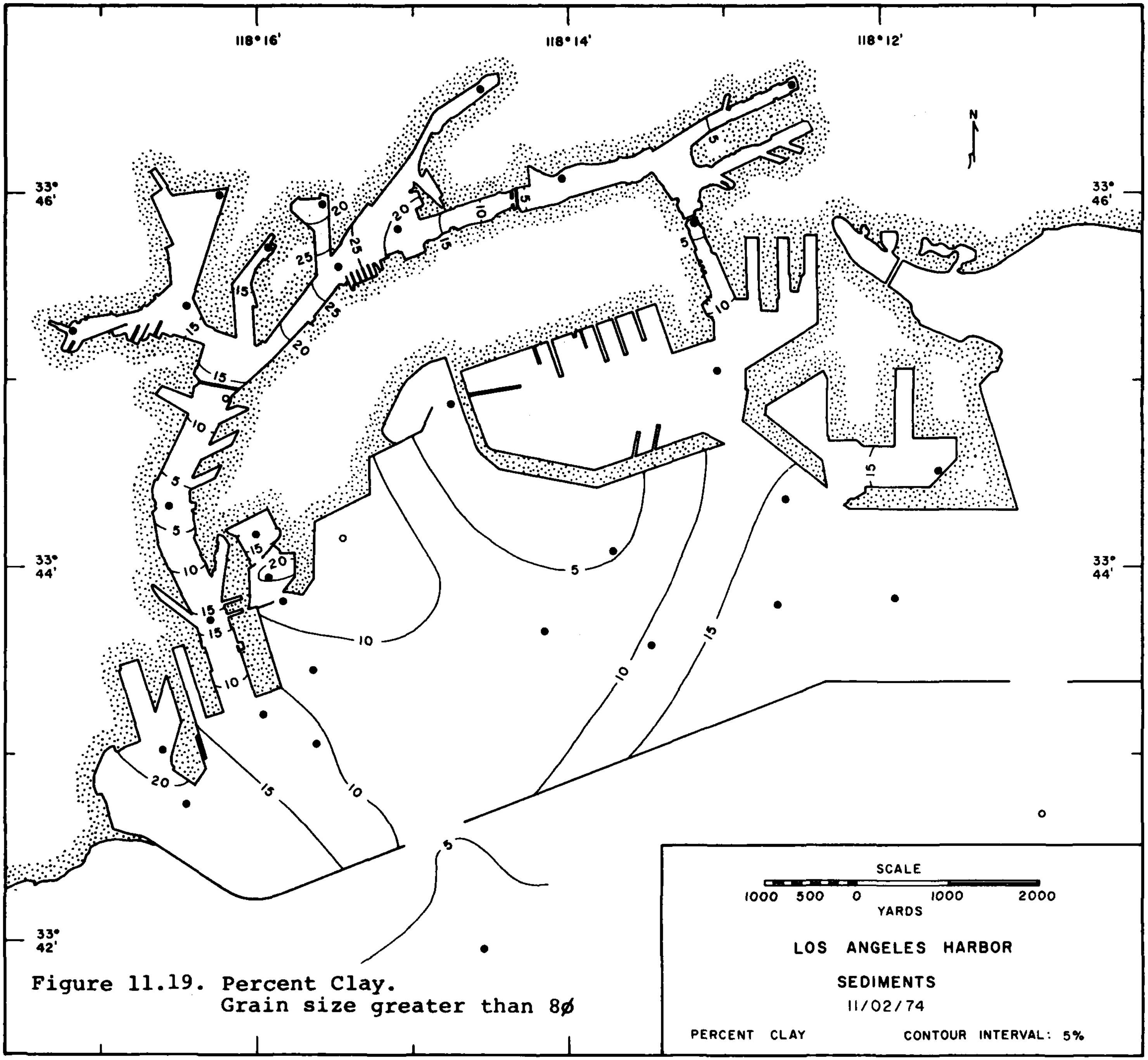


Figure 11.19. Percent Clay.
Grain size greater than 8ø

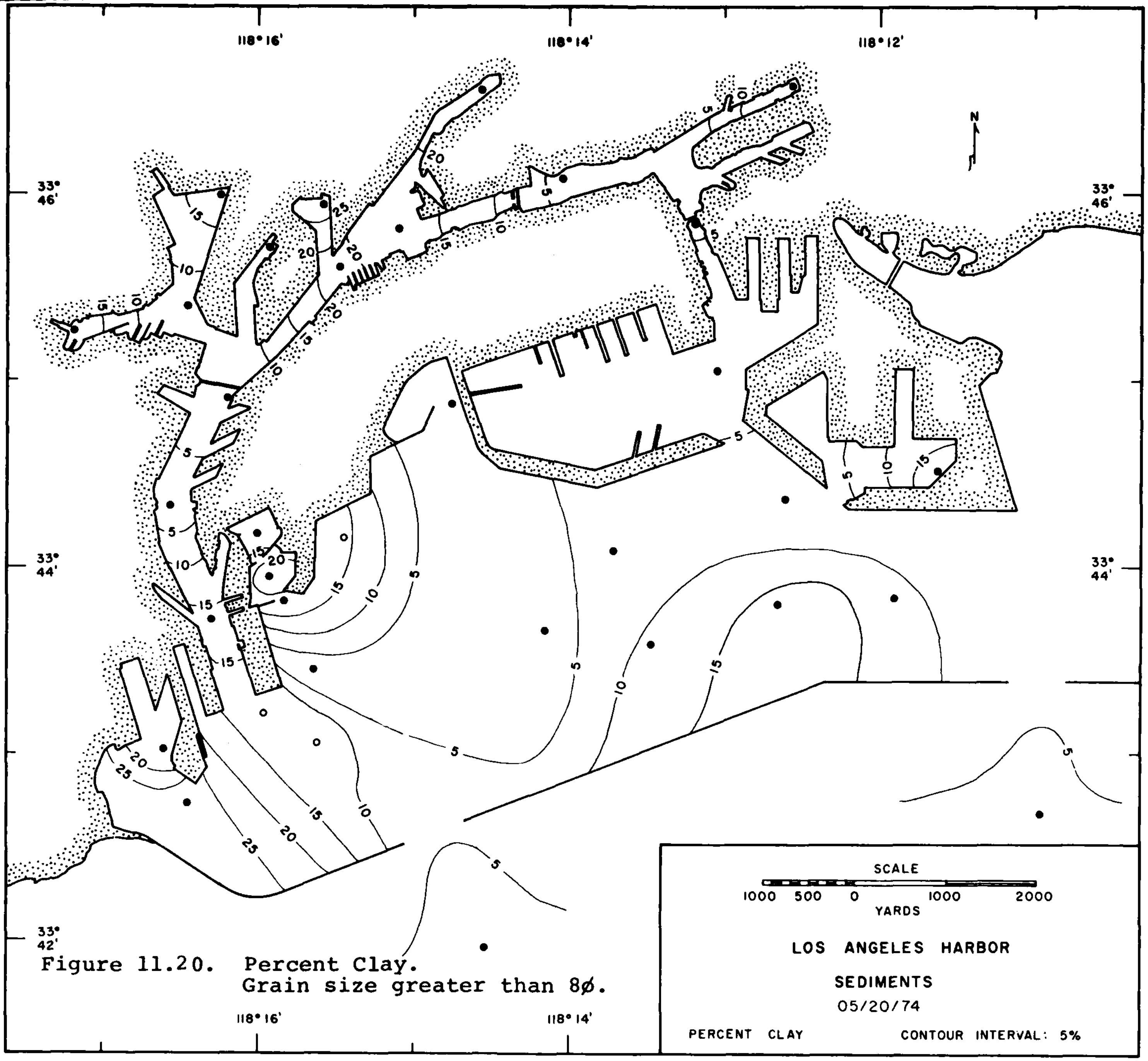


Figure 11.20. Percent Clay.
Grain size greater than 8ø.

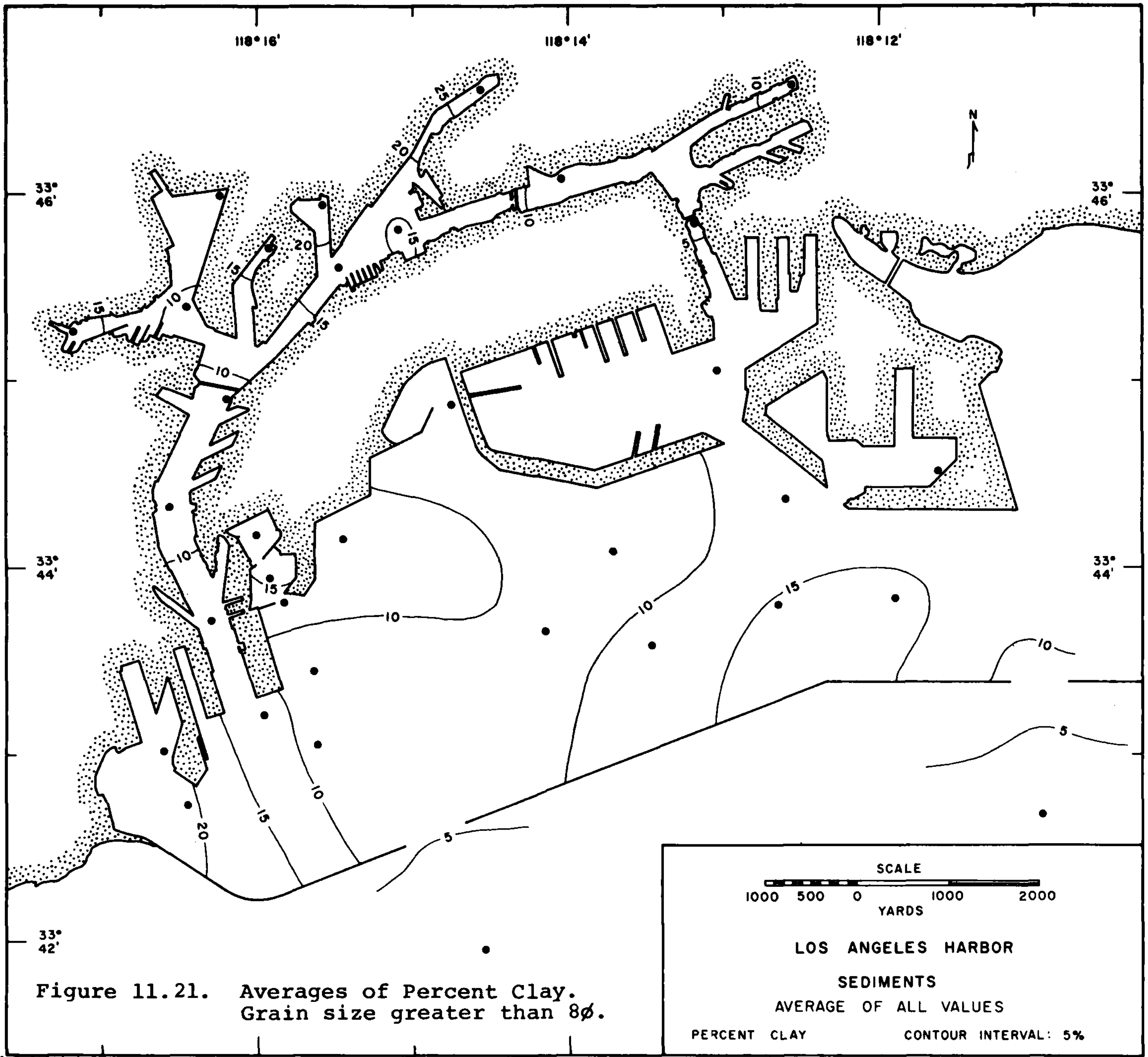


Figure 11.21. Averages of Percent Clay. Grain size greater than 8ϕ.

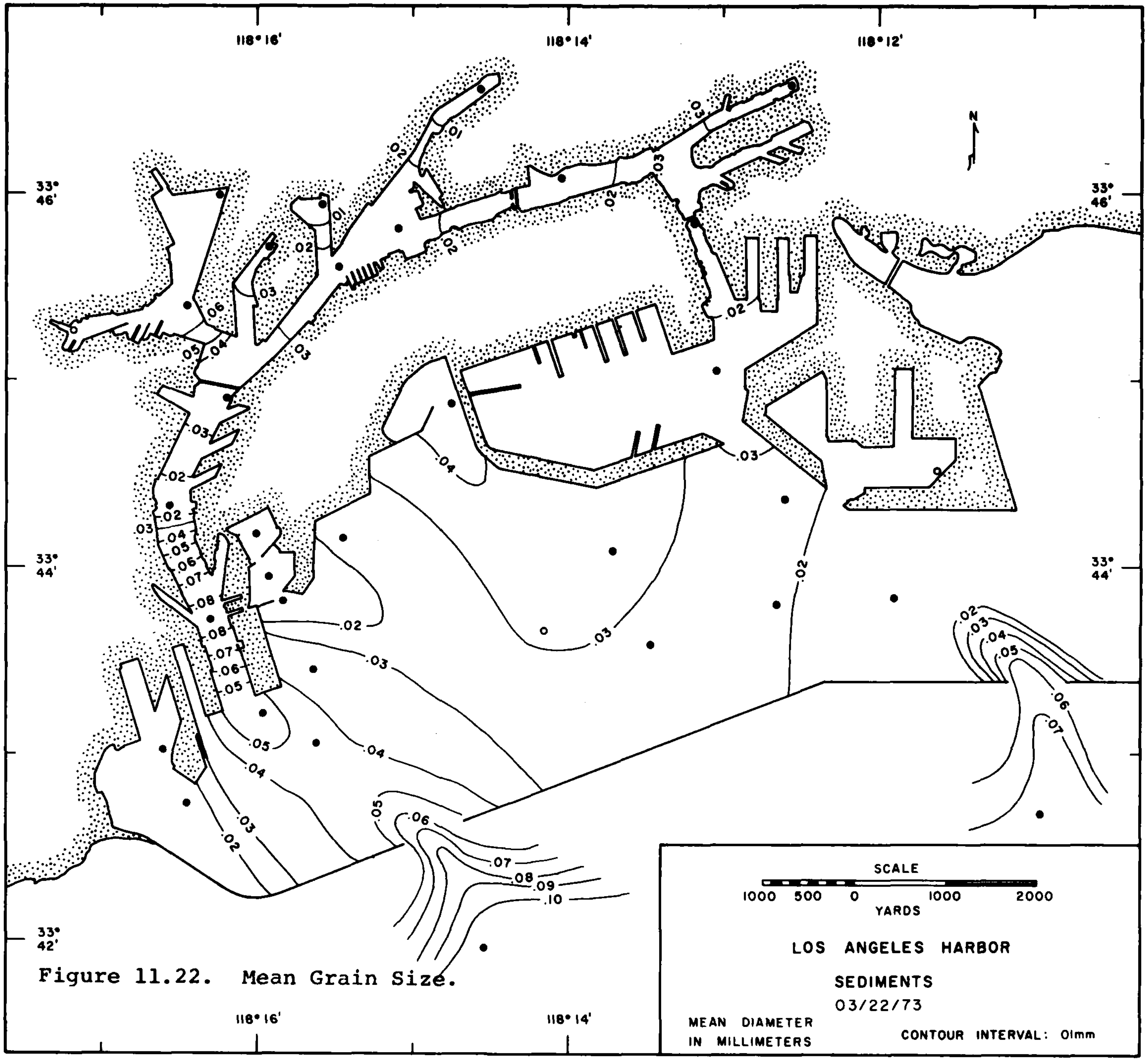


Figure 11.22. Mean Grain Size.

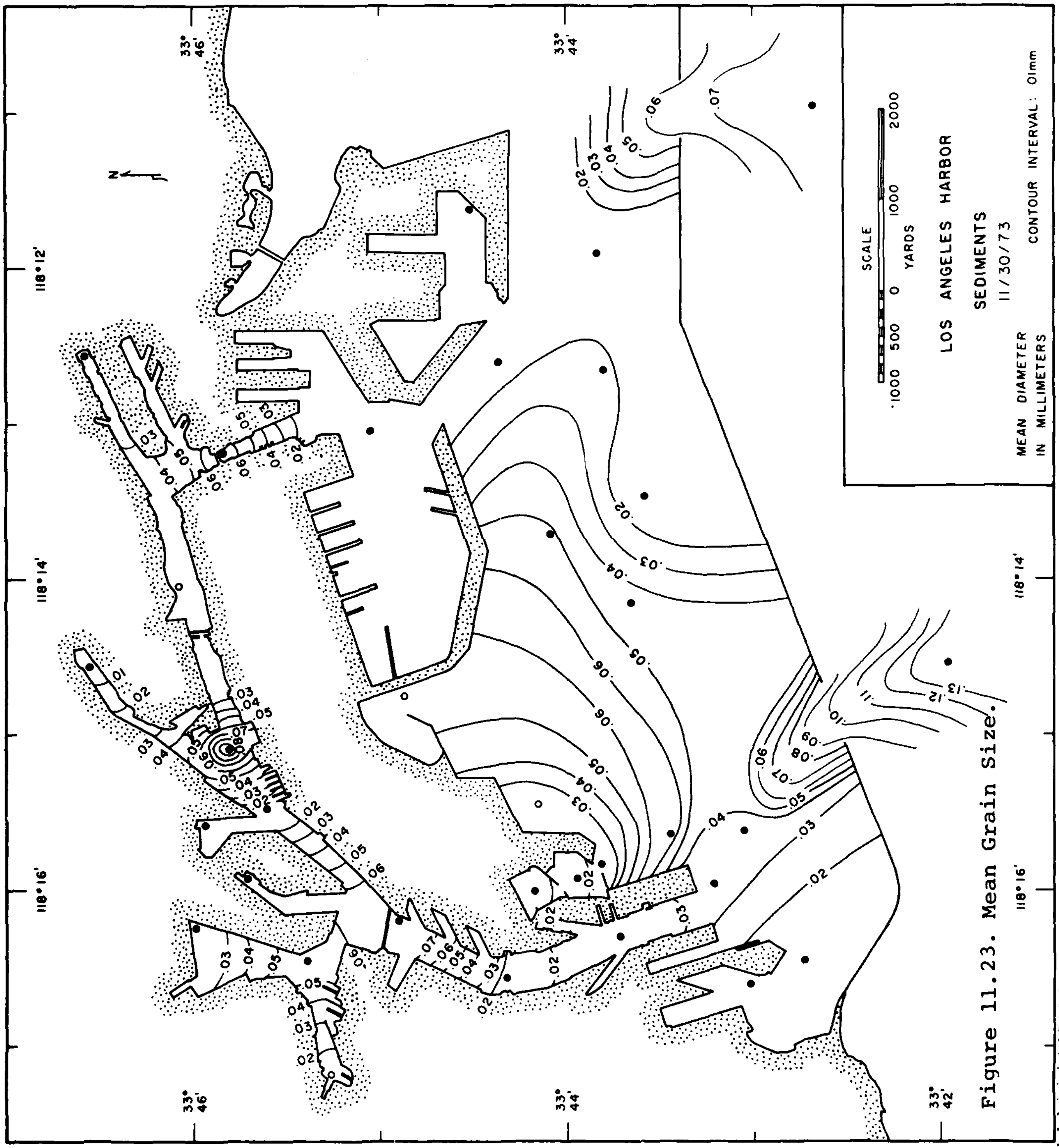
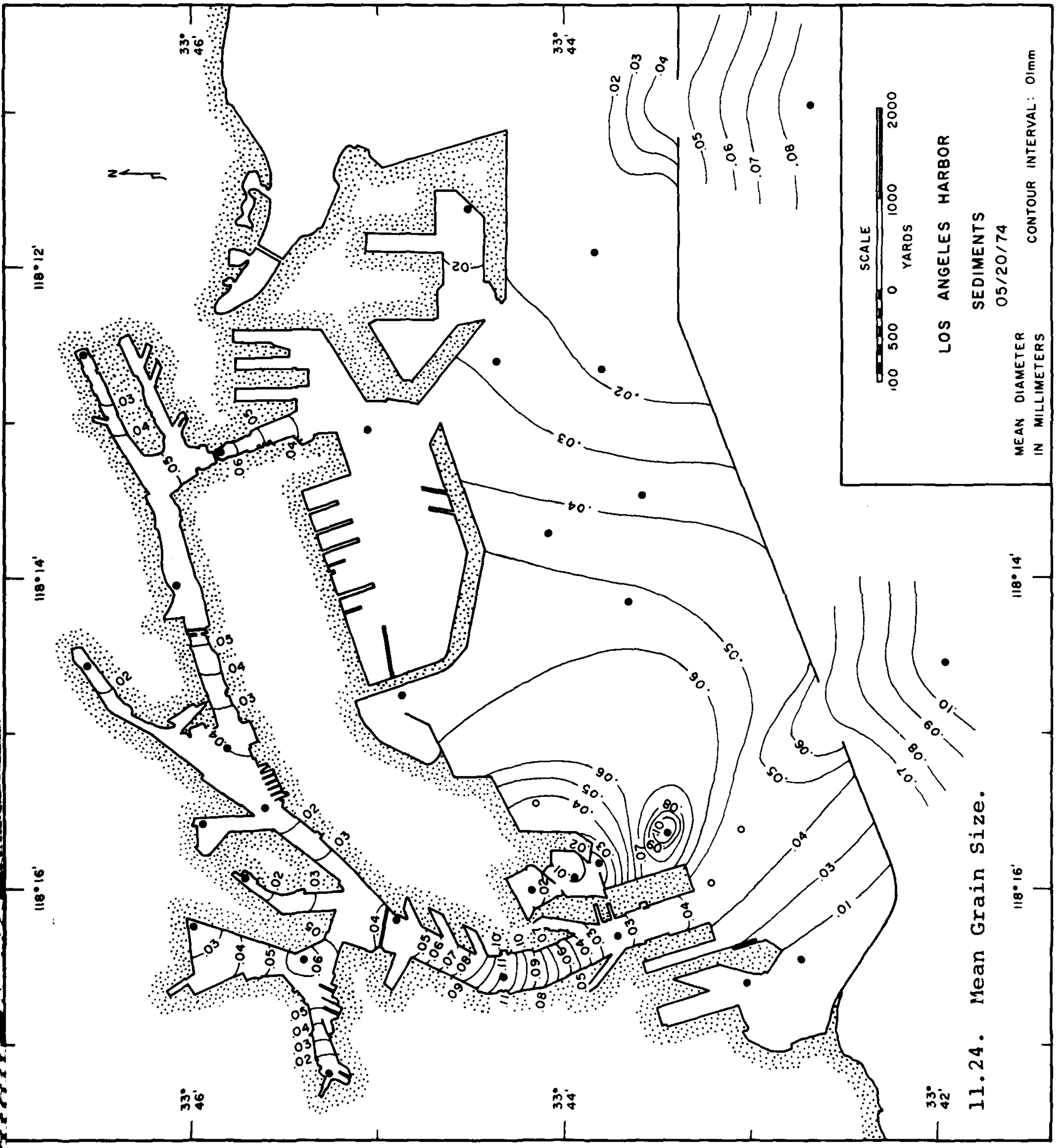


Figure 11.23. Mean Grain Size.



11.24. Mean Grain Size.

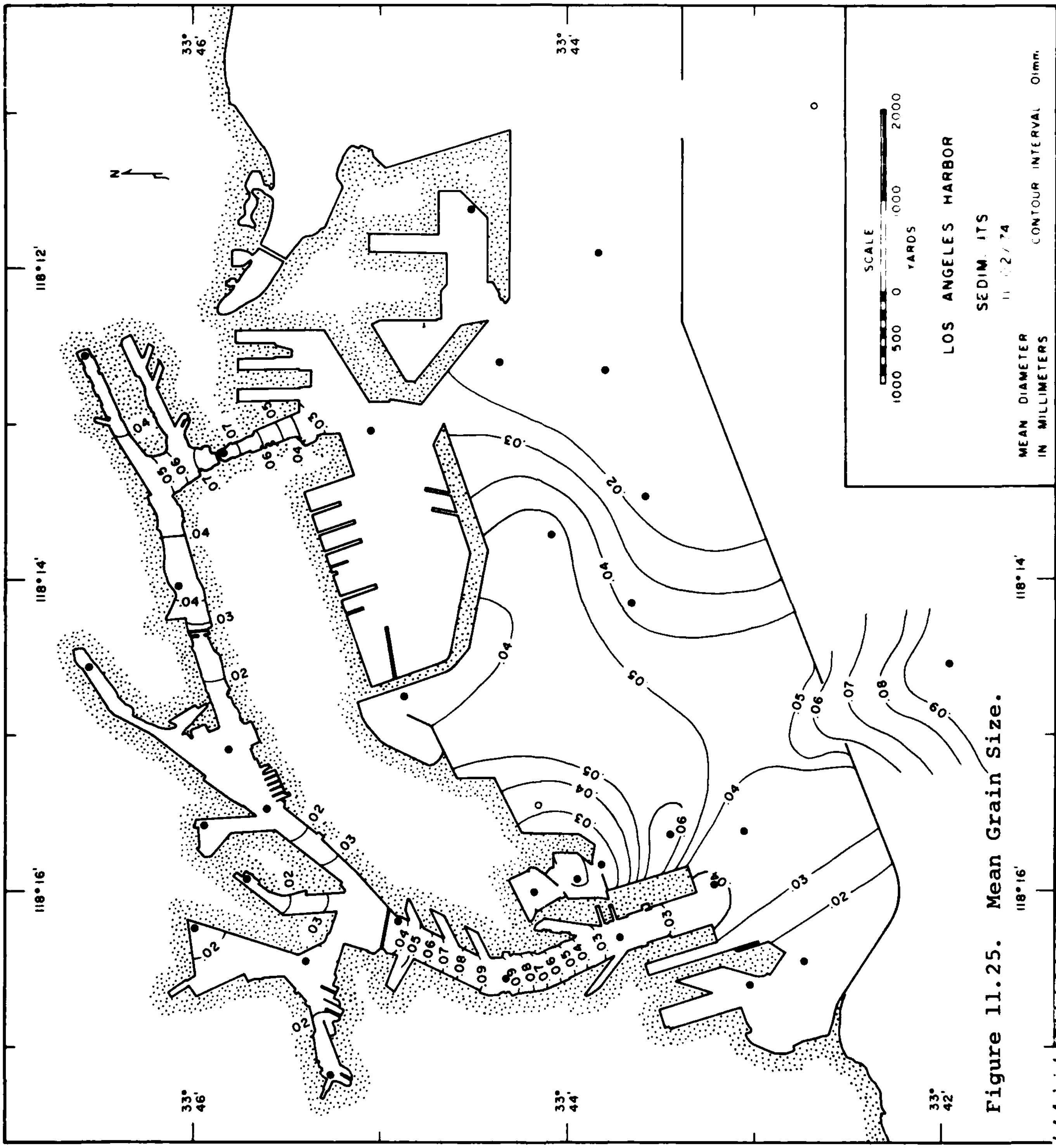


Figure 11.25. Mean Grain Size.

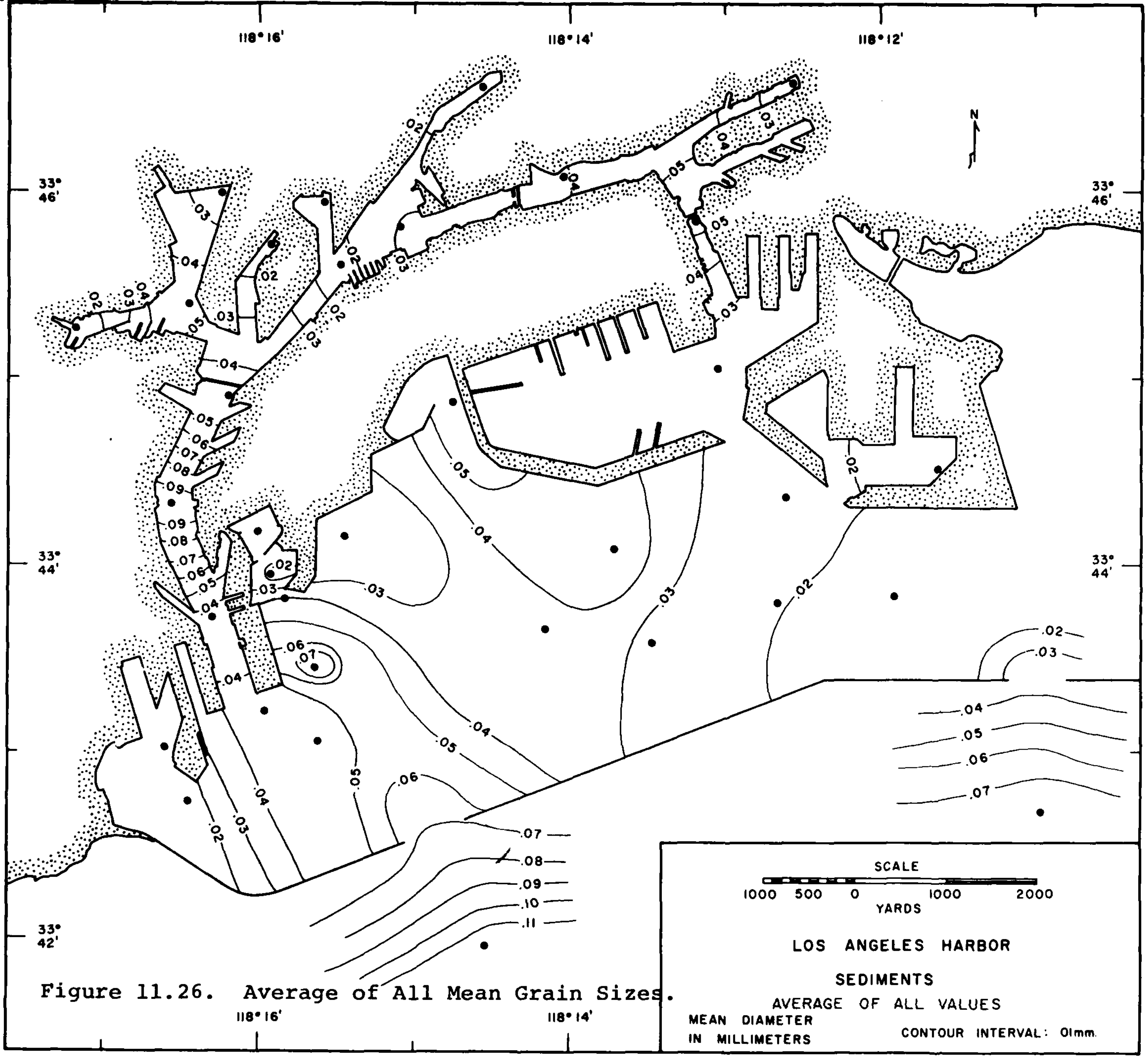


Figure 11.26. Average of All Mean Grain Sizes.

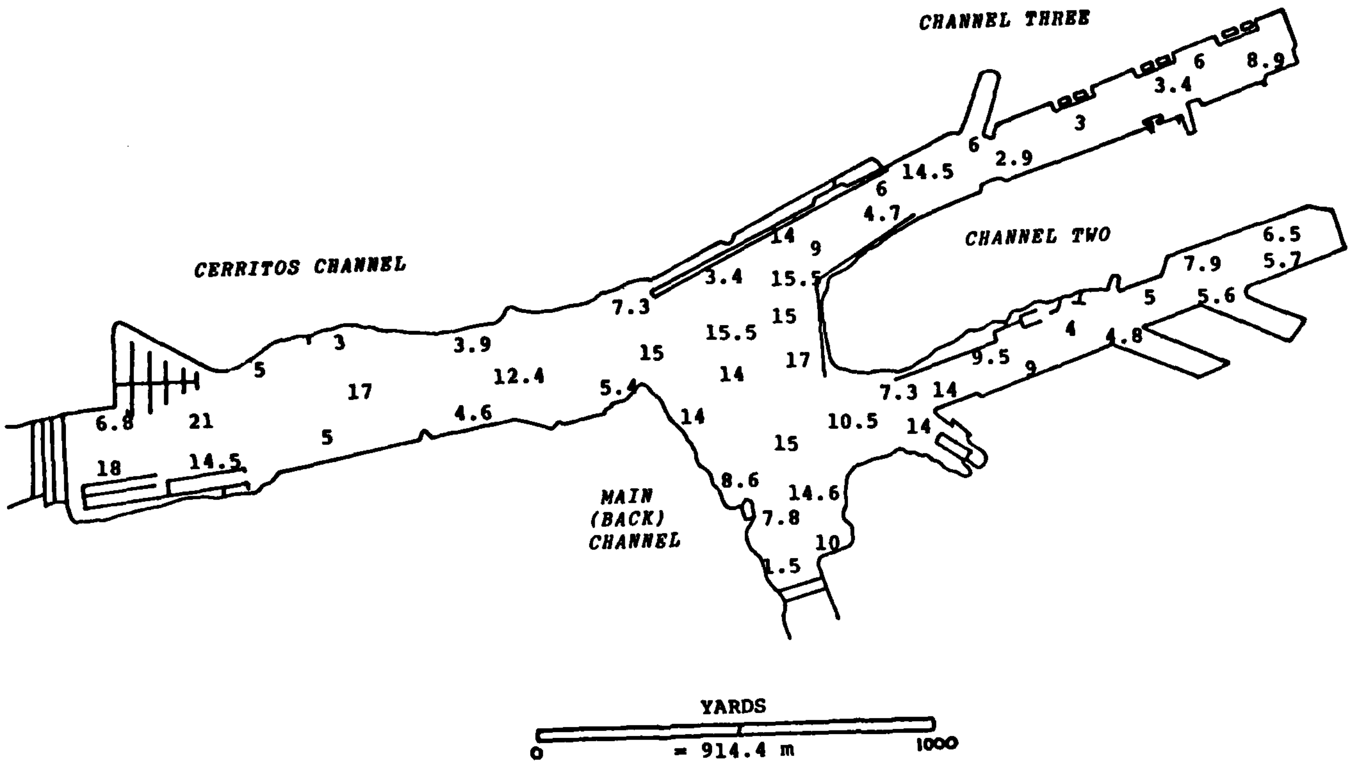


Figure 11.27. Percent Clay in Inner Channels, Port of Long Beach.

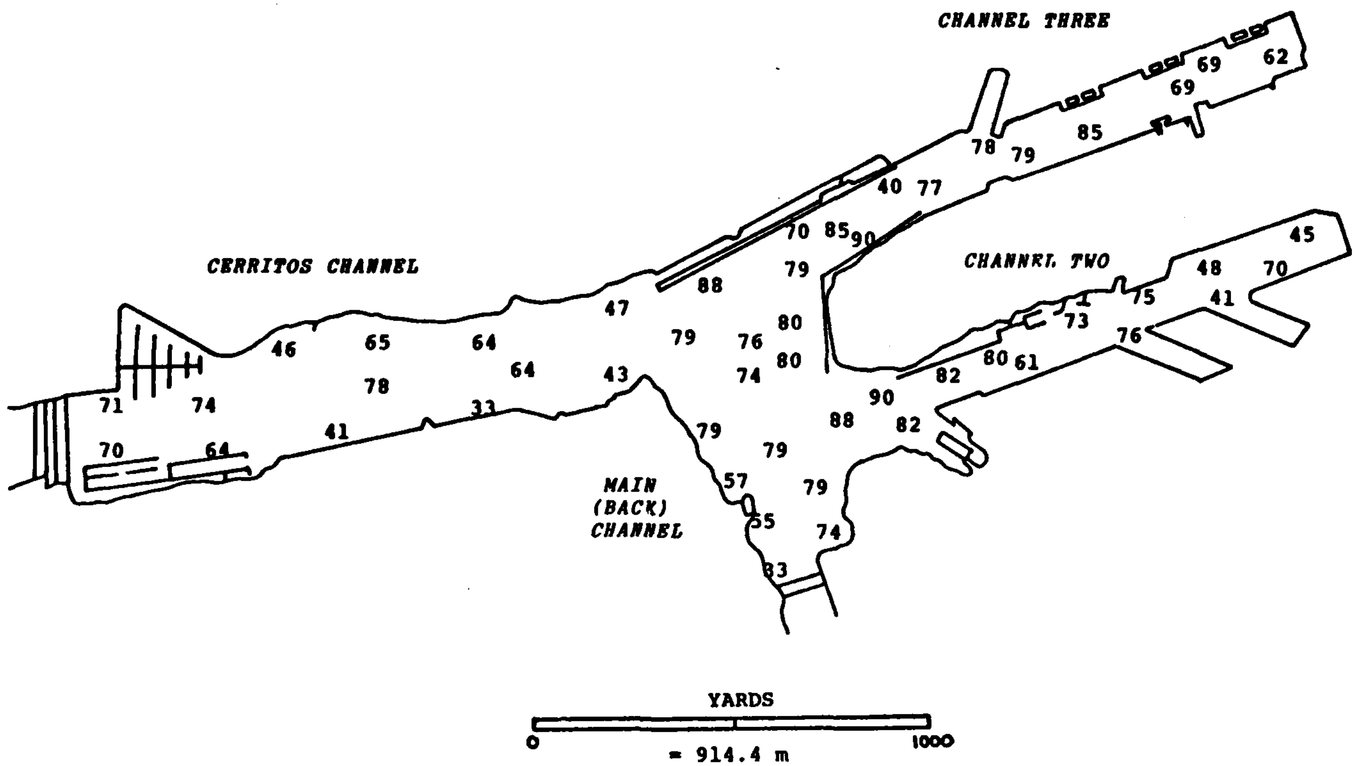


Figure 11.28. Percent Silt in Inner Channels, Port of Long Beach.

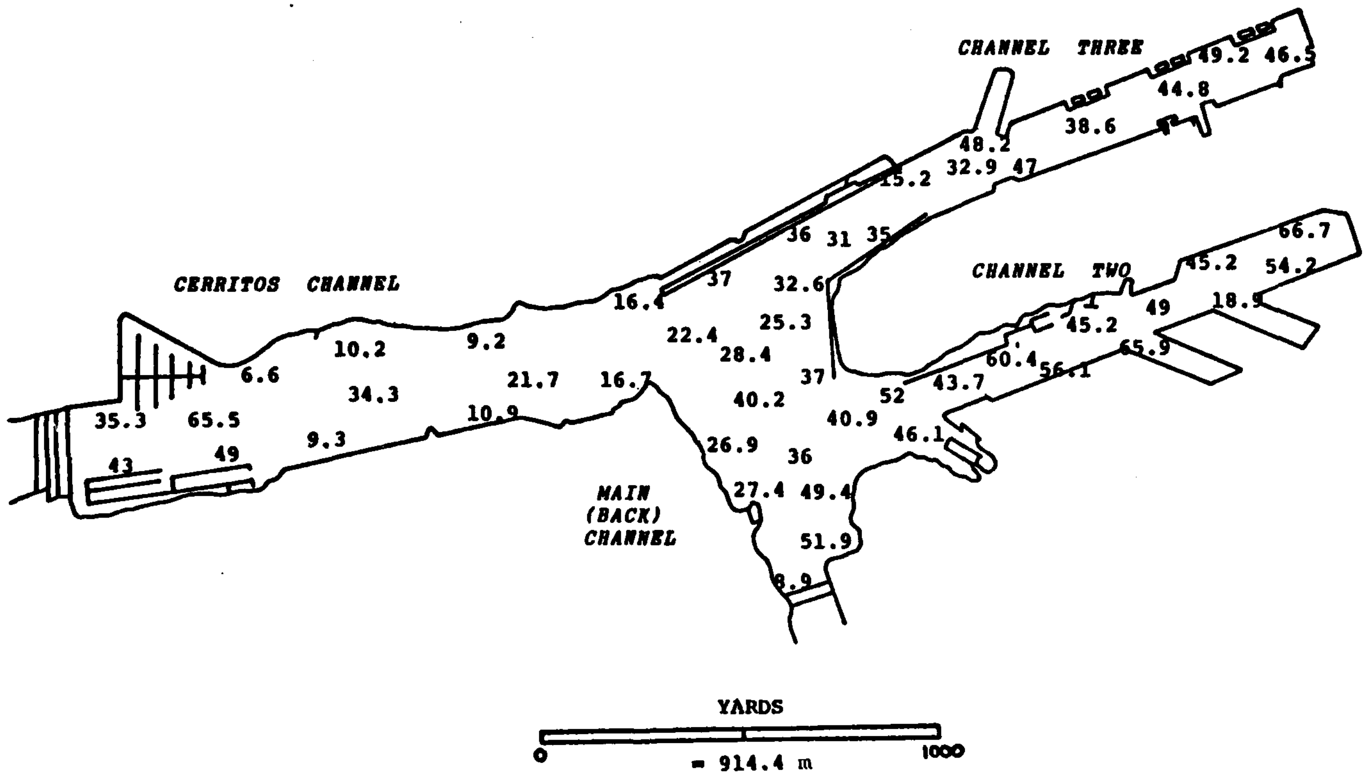


Figure 11.29. Oil and Grease, Sediment Samples. (x 100 = ppm)

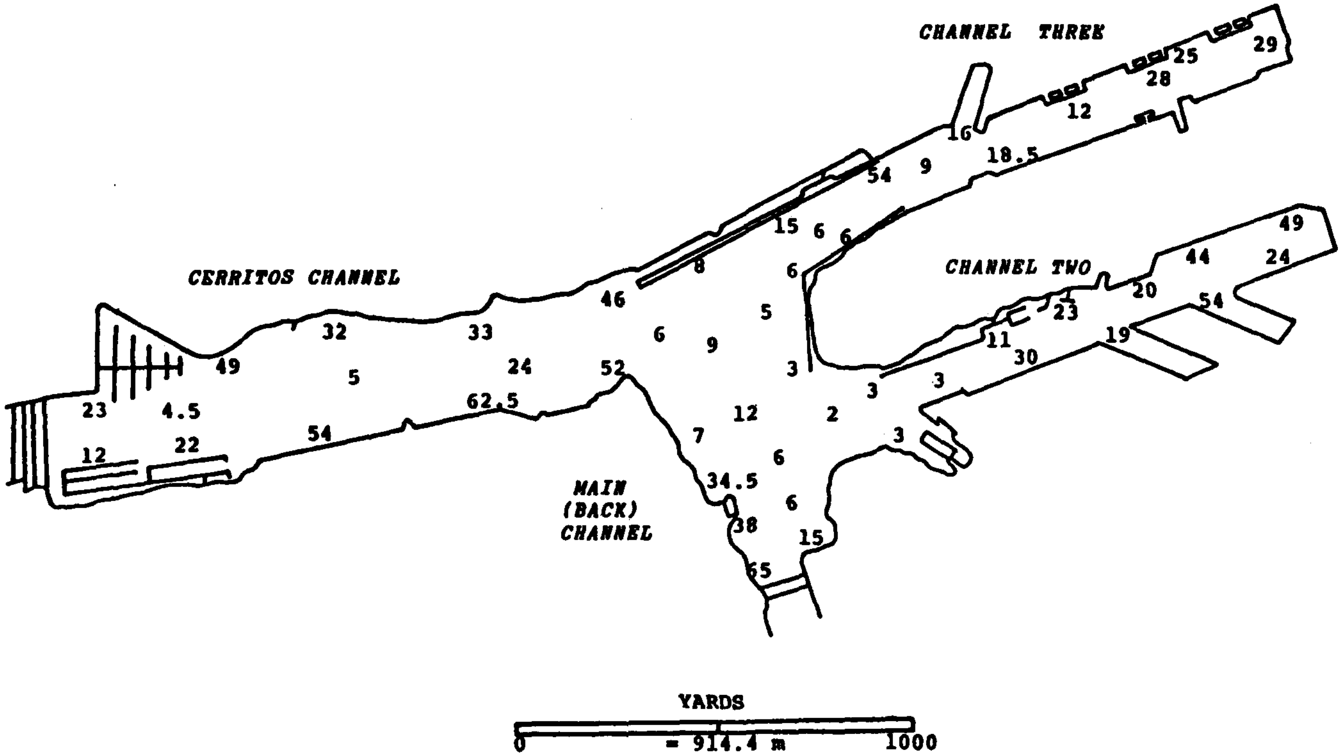


Figure 11.30. **Percent Sand in Inner Channels, Port of Long Beach.**

Figure 11.31.
Total Organic Carbon

```
DATA VALUE EXTREMES ARE          0.10        2.86


TOTAL MISSING DATA POINTS IS        5


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
       ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM      0.10      0.38      0.65      0.93      1.20      1.48      1.76      2.03      2.31      2.59
  MAXIMUM      0.38      0.65      0.93      1.20      1.48      1.76      2.03      2.31      2.59      2.86

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

              10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1         2         3         4         5         6         7         8         9        10
          ==================================================================================================
           .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  ■■■■■■■■■  ■■■■■■■■■  ■■■■■■■■■
           .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  ■■■■■■■■■  ■■■■■■■■■  ■■■■■■■■■
  SYMBOLS  ....1....  ''''2''''  ----3----  ====4====  ++++5++++  XXXX6XXXX  OOOO7OOOO  ■■■■8■■■■  ■■■■9■■■■  ■■■■■■■■■
           .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  ■■■■■■■■■  ■■■■■■■■■  ■■■■■■■■■
           .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  ■■■■■■■■■  ■■■■■■■■■  ■■■■■■■■■
          ==================================================================================================
  FREQ.          6         2        10         4         5         5         5         1         0         1
          1   I..1..I   I''2''I   I--3--I   I==4==I   I++5++I   IXX6XXI   IOO7OOI   I■■■■■I              I■■■■■I
          2   I..1..I   I''2''I   I--3--I   I==4==I   I++5++I   IXX6XXI   IOO7OOI
          3   I..1..I             I--3--I   I==4==I   I++5++I   IXX6XXI   IOO7OOI
          4   I..1..I             I--3--I   I==4==I   I++5++I   IXX6XXI   IOO7OOI
          5   I..1..I             I--3--I             I++5++I   IXX6XXI   IOO7OOI
          6   I..1..I             I--3--I
          7                       I--3--I
          8                       I--3--I
          9                       I--3--I
         10                       I--3--I

TIME =    0.0
```

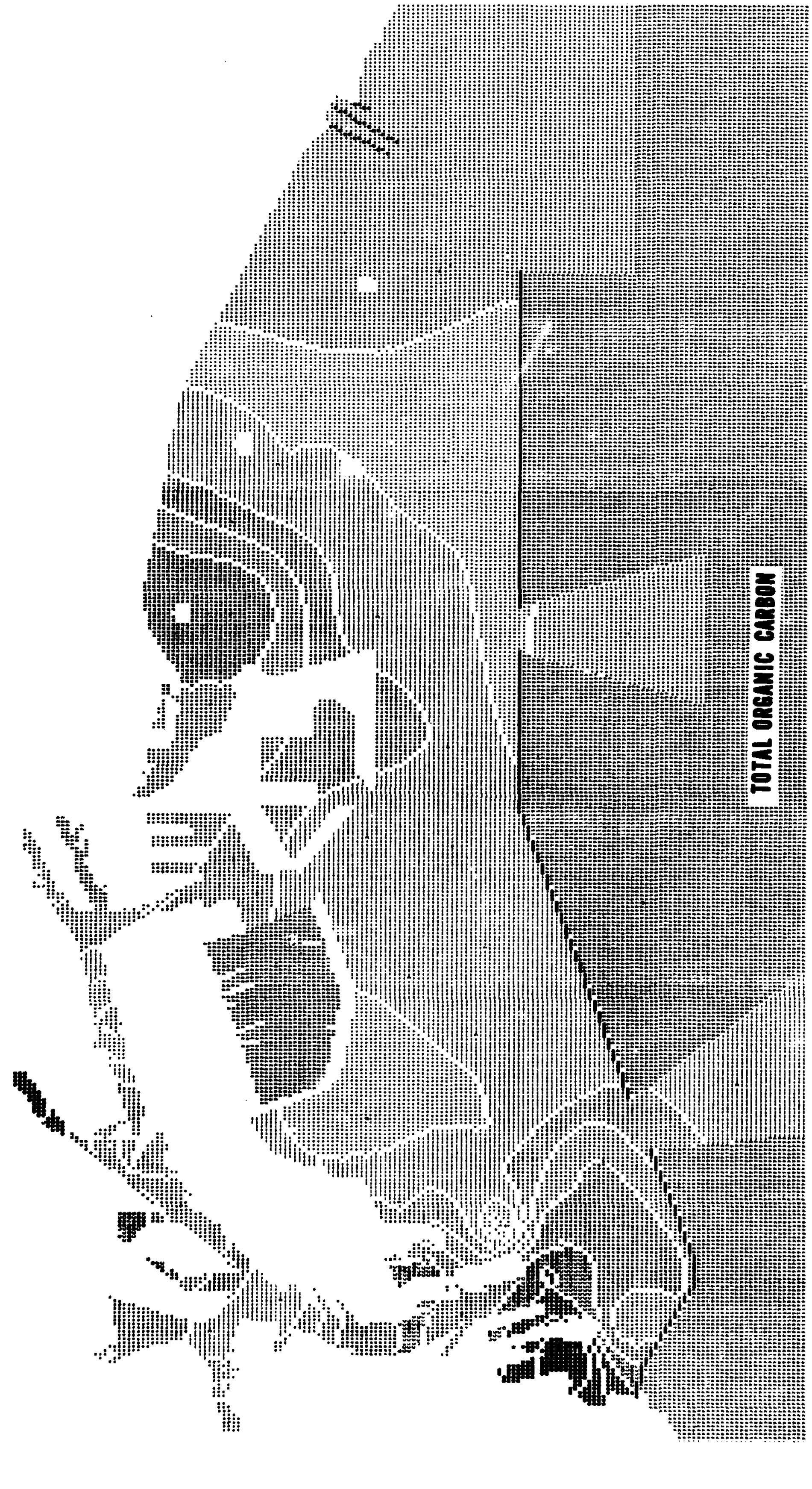


Figure 11.31.

Figure 11.32.
Log Sediment Chemical Oxygen Demand

```
DATA VALUE EXTREMES ARE          8.89        11.93


TOTAL MISSING DATA POINTS IS          5


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM        8.89      9.20      9.50      9.80     10.11     10.41     10.71     11.02     11.32     11.62
 MAXIMUM        9.20      9.50      9.80     10.11     10.41     10.71     11.02     11.32     11.62     11.93

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL            1         2         3         4         5         6         7         8         9        10
          ==================================================================================================
           .........  ''''''''' --------- ========= +++++++++ XXXXXXXXX OOOOOOOOO @@@@@@@@@ @@@@@@@@@ @@@@@@@@@
           .........  ''''''''' --------- ========= +++++++++ XXXXXXXXX OOOOOOOOO @@@@@@@@@ @@@@@@@@@ @@@@@@@@@
 SYMBOLS   ....1....  ''''2'''' ----3---- ====4==== ++++5++++ XXXX6XXXX OOOO7OOOO @@@@8@@@@ @@@@9@@@@ @@@@*@@@@
           .........  ''''''''' --------- ========= +++++++++ XXXXXXXXX OOOOOOOOO @@@@@@@@@ @@@@@@@@@ @@@@@@@@@
           .........  ''''''''' --------- ========= +++++++++ XXXXXXXXX OOOOOOOOO @@@@@@@@@ @@@@@@@@@ @@@@@@@@@
          ==================================================================================================
 FREQ.            2         0         4         5         3         8         8         7         1         1
        1    I..1..I             I--3--I   I==4==I   I++5++I   IXX6XXI   IOO7OOI   I@@8@@I   I@@9@@I   I@@*@@I
        2    I..1..I             I--3--I   I==4==I   I++5++I   IXX6XXI   IOO7OOI   I@@8@@I
        3                        I--3--I   I==4==I   I++5++I   IXX6XXI   IOO7OOI   I@@8@@I
        4                        I--3--I   I==4==I             IXX6XXI   IOO7OOI   I@@8@@I
        5                                  I==4==I             IXX6XXI   IOO7OOI   I@@8@@I
        6                                                      IXX6XXI   IOO7OOI   I@@8@@I
        7                                                      IXX6XXI   IOO7OOI   I@@8@@I
        8                                                      IXX6XXI   IOO7OOI

 TIME =    0.0
```

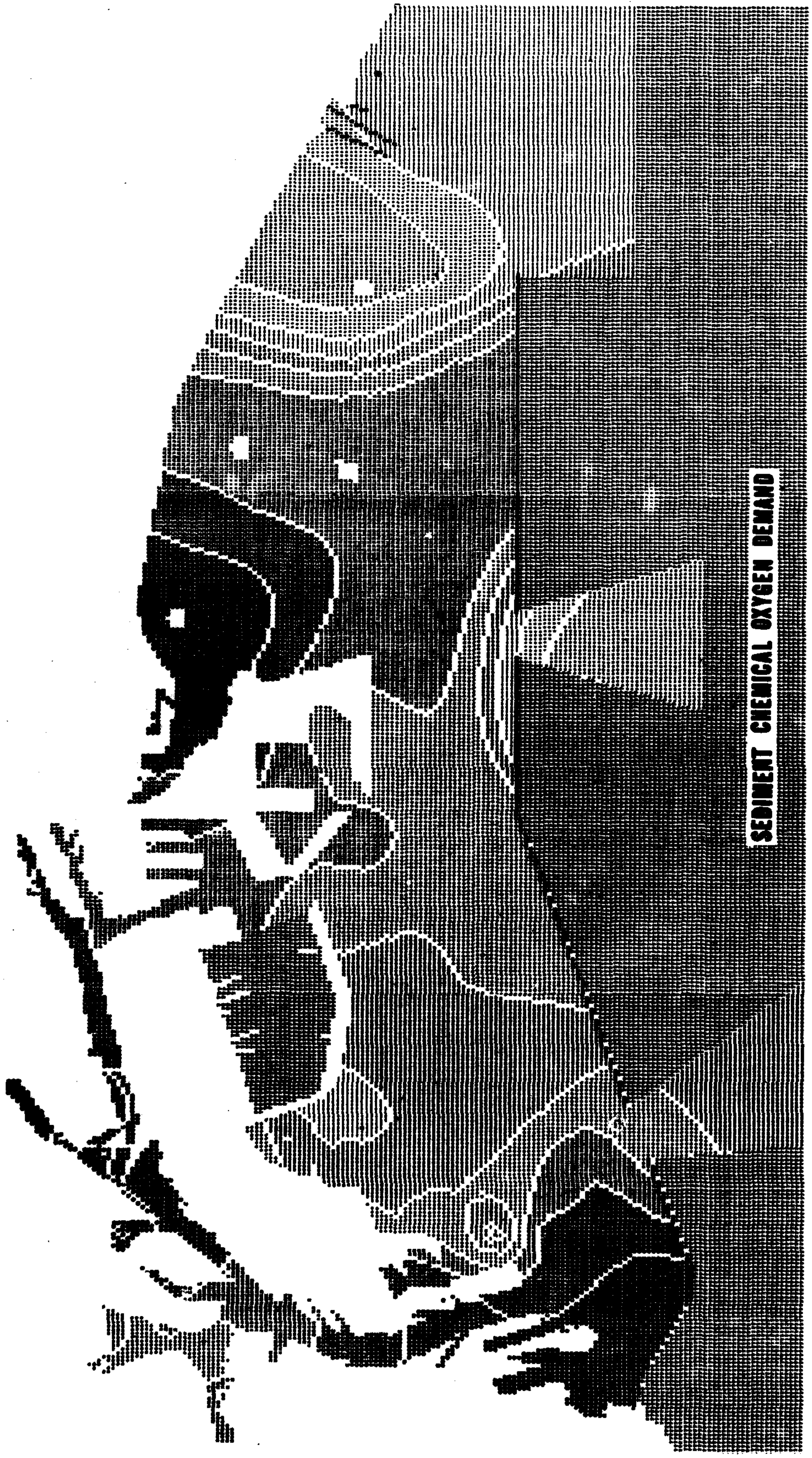


Figure 11.32.

Figure 11.33.

Sediment Immediate Oxygen Demand

```
DATA VALUE EXTREMES ARE          96.00      2511.50


TOTAL MISSING DATA POINTS IS          5


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM      96.00     337.55     579.10     820.65    1062.20    1303.75    1545.30    1786.85    2028.40    2269.95
  MAXIMUM     337.55     579.10     820.65    1062.20    1303.75    1545.30    1786.85    2028.40    2269.95    2511.50

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               10.00      10.00      10.00      10.00      10.00      10.00      10.00      10.00      10.00      10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL            1         2         3         4         5         6         7         8         9        10
           ==================================================================================================
           .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  @@@@@@@@@  @@@@@@@@@  @@@@@@@@@
           .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  @@@@@@@@@  @@@@@@@@@  @@@@@@@@@
  SYMBOLS  ....1....  ''''2''''  ----3----  ====4====  ++++5++++  XXXX6XXXX  OOOO7OOOO  @@@@@@@@@  @@@@9@@@@  @@@@*@@@@
           .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  @@@@@@@@@  @@@@@@@@@  @@@@@@@@@
           .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  @@@@@@@@@  @@@@@@@@@  @@@@@@@@@
           ==================================================================================================
  FREQ.           6         9         8         9         0         3         1         1         0         2
        1     I..1..I   I''2''I   I--3--I   I==4==I             IXX6XXI   IOO7OOI   I@@@@@I             I@@*@@I
        2     I..1..I   I''2''I   I--3--I   I==4==I             IXX6XXI                                 I@@*@@I
        3     I..1..I   I''2''I   I--3--I   I==4==I             IXX6XXI
        4     I..1..I   I''2''I   I--3--I   I==4==I
        5     I..1..I   I''2''I   I--3--I   I==4==I
        6     I..1..I   I''2''I   I--3--I   I==4==I
        7               I''2''I   I--3--I   I==4==I
        8               I''2''I   I--3--I   I==4==I
        9               I''2''I             I==4==I

TIME =    0.0
```

Figure 11.33.

Figure 11.34.

Sediment Arsenic

```
DATA VALUE EXTREMES ARE          0.04        20.80


TOTAL MISSING DATA POINTS IS          5


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
       ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM       0.04      2.12      4.19      6.27      8.34     10.42     12.49     14.57     16.65     18.72
 MAXIMUM       2.12      4.19      6.27      8.34     10.42     12.49     14.57     16.65     18.72     20.80


PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

              10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00


FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL          1         2         3         4         5         6         7         8         9        10
           ==========================================================================================
            .........  .........  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  @@@@@@@@@  @@@@@@@@@  @@@@@@@@@
            .........  .........  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  @@@@@@@@@  @@@@@@@@@  @@@@@@@@@
 SYMBOLS    ....1....  ....2....  ----3----  ====4====  ++++5++++  XXXX6XXXX  OOOO7OOOO  @@@@8@@@@  @@@@9@@@@  @@@@+@@@@
            .........  .........  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  @@@@@@@@@  @@@@@@@@@  @@@@@@@@@
            .........  .........  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  @@@@@@@@@  @@@@@@@@@  @@@@@@@@@
           ==========================================================================================
 FREQ.          2         8         4         7         7         4         2         1         3         1
         1   I..1..I   I..2..I   I--3--I   I==4==I   I++5++I   IXX6XXI   IOO7OOI   I@@8@@I   I@@9@@I   I@@+@@I
         2   I..1..I   I..2..I   I--3--I   I==4==I   I++5++I   IXX6XXI   IOO7OOI             I@@9@@I
         3             I..2..I   I--3--I   I==4==I   I++5++I   IXX6XXI                       I@@9@@I
         4             I..2..I   I--3--I   I==4==I   I++5++I   IXX6XXI
         5             I..2..I             I==4==I   I++5++I
         6             I..2..I             I==4==I   I++5++I
         7             I..2..I             I==4==I   I++5++I
         8             I..2..I
```

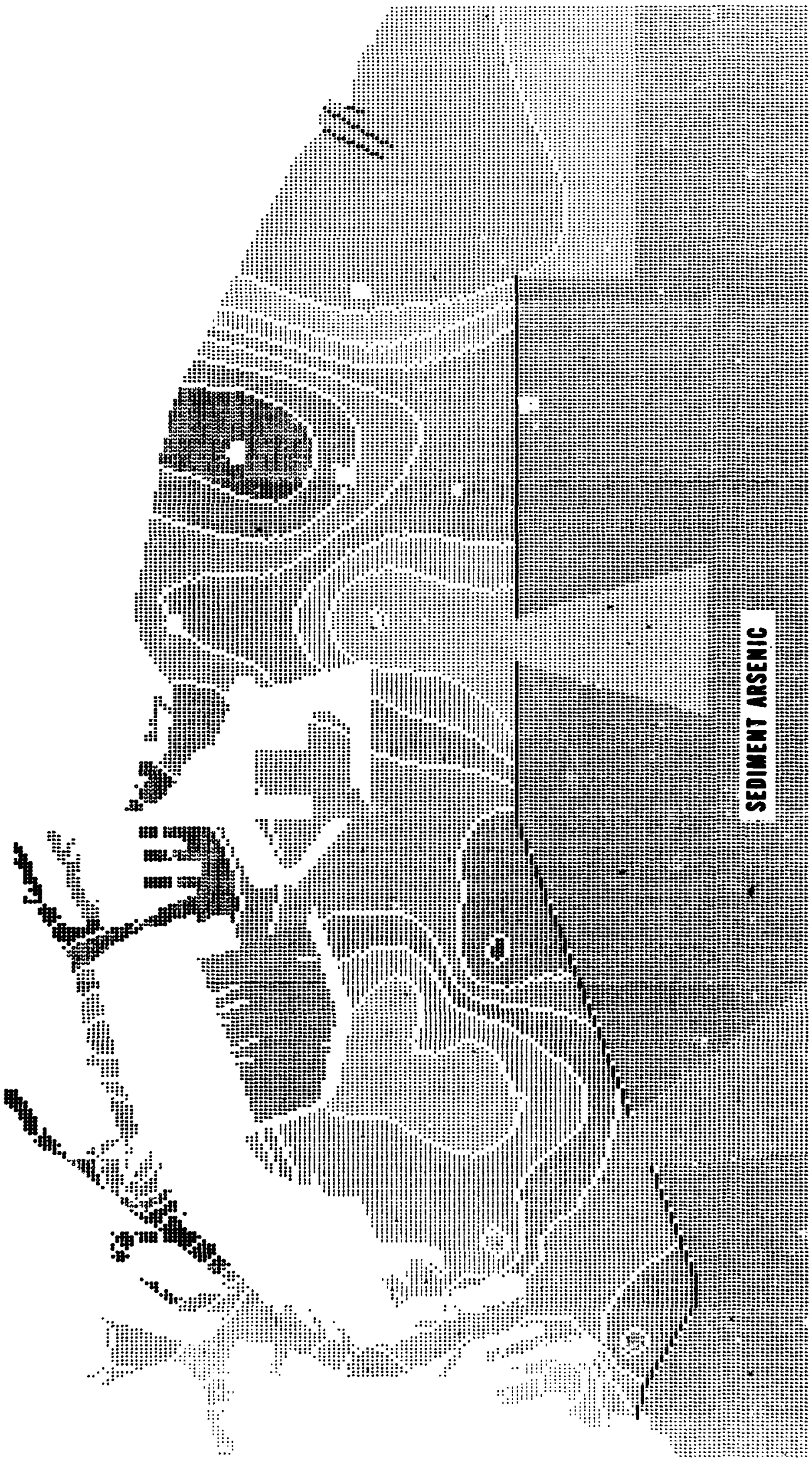
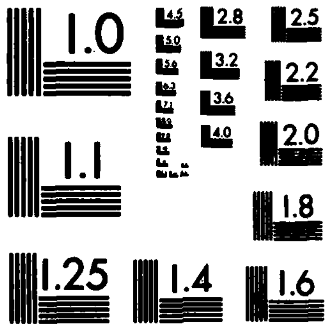


Figure 11.34.

AD-A136 653 ENVIRONMENTAL INVESTIGATIONS AND ANALYSES FOR LOS 6/8
ANGELES-LONG BEACH HARB..(U) UNIVERSITY OF SOUTHERN
CALIFORNIA LOS ANGELES ALLAN HANCOCK F.. DEC 76
UNCLASSIFIED DACW09-73-C-0112 F/G 8/10 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Figure 11.35.

Sediment Cadmium

```
DATA VALUE EXTREMES ARE          0.70        6.51


TOTAL MISSING DATA POINTS IS        5


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
       ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM      0.70      1.48      2.26      3.04      3.83      4.61      5.39      6.17      6.95      7.73
  MAXIMUM      1.48      2.26      3.04      3.83      4.61      5.39      6.17      6.95      7.73      8.51


PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

              10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00


FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL           1         2         3         4         5         6         7         8         9        10
           ==========================================================================================================
            .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  000000000  @@@@@@@@@  @@@@@@@@@  @@@@@@@@@
            .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  000000000  @@@@@@@@@  @@@@@@@@@  @@@@@@@@@
 SYMBOLS    ....1....  ''''2''''  ----3----  ====4====  ++++5++++  XXXX6XXXX  000070000  @@@@8@@@@  @@@@9@@@@  @@@@+@@@@
            .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  000000000  @@@@@@@@@  @@@@@@@@@  @@@@@@@@@
            .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  000000000  @@@@@@@@@  @@@@@@@@@  @@@@@@@@@
           ==========================================================================================================
 FREQ.           3         5         8         6         5         6         2         1         0         1
        1    I..1..I   I''2''I   I--3--I   I==4==I   I++5++I   IXX6XXI   I00700I   I@@8@@I             I@@+@@I
        2    I..1..I   I''2''I   I--3--I   I==4==I   I++5++I   IXX6XXI   I00700I
        3    I..1..I   I''2''I   I--3--I   I==4==I   I++5++I   IXX6XXI
        4              I''2''I   I--3--I   I==4==I   I++5++I   IXX6XXI
        5              I''2''I   I--3--I   I==4==I   I++5++I   IXX6XXI
        6                        I--3--I   I==4==I             IXX6XXI
        7                        I--3--I   I==4==I
        8                        I--3--I   I==4==I
```

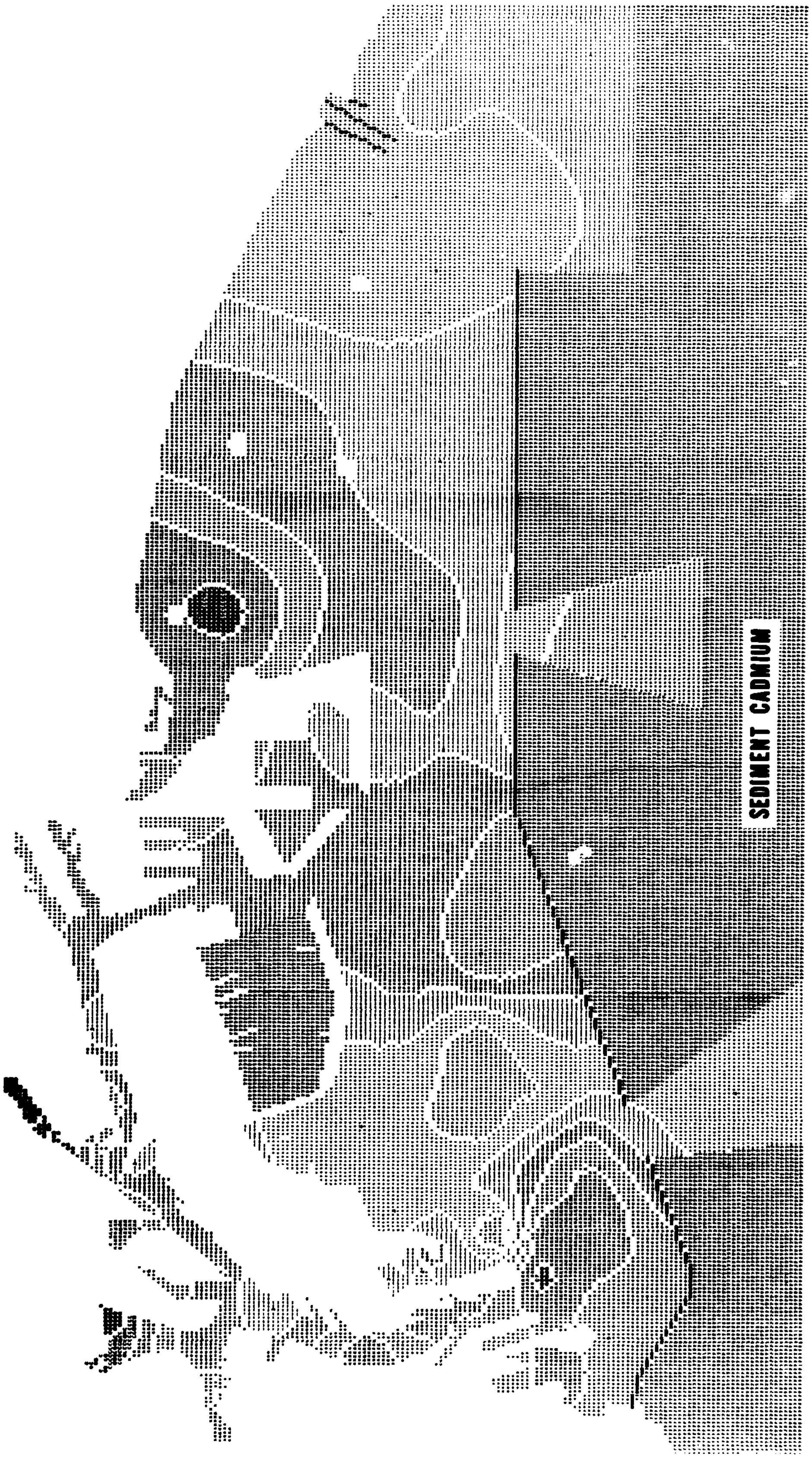


Figure 11.35.

Figure 11.36.
Sediment Chromium

```
DATA VALUE EXTREMES ARE        14.00      360.00


TOTAL MISSING DATA POINTS IS        5


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM     14.00     48.60     83.20    117.80    152.40    187.00    221.60    256.20    290.80    325.40
  MAXIMUM     48.60     83.20    117.80    152.40    187.00    221.60    256.20    290.80    325.40    360.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

              10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL         1         2         3         4         5         6         7         8         9        10
          ==========================================================================================================
           .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO
           .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO
  SYMBOLS  ....1....  ''''2''''  ----3----  ====4====  ++++5++++  XXXX6XXXX  OOOO7OOOO
           .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO
           .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO
          ==========================================================================================================
  FREQ.        11        17         3         3         2         0         1         1         0         1
         1  I..1..I   I''2''I   I--3--I   I==4==I   I++5++I             IOO7OOI
         2  I..1..I   I''2''I   I--3--I   I==4==I   I++5++I
         3  I..1..I   I''2''I   I--3--I   I==4==I
         4  I..1..I   I''2''I
         5  I..1..I   I''2''I
         6  I..1..I   I''2''I
         7  I..1..I   I''2''I
         8  I..1..I   I''2''I
         9  I..1..I   I''2''I
        10  I..1..I   I''2''I
        11  I..1..I   I''2''I
        12            I''2''I
        13            I''2''I
        14            I''2''I
        15            I''2''I
        16            I''2''I
        17            I''2''I
```

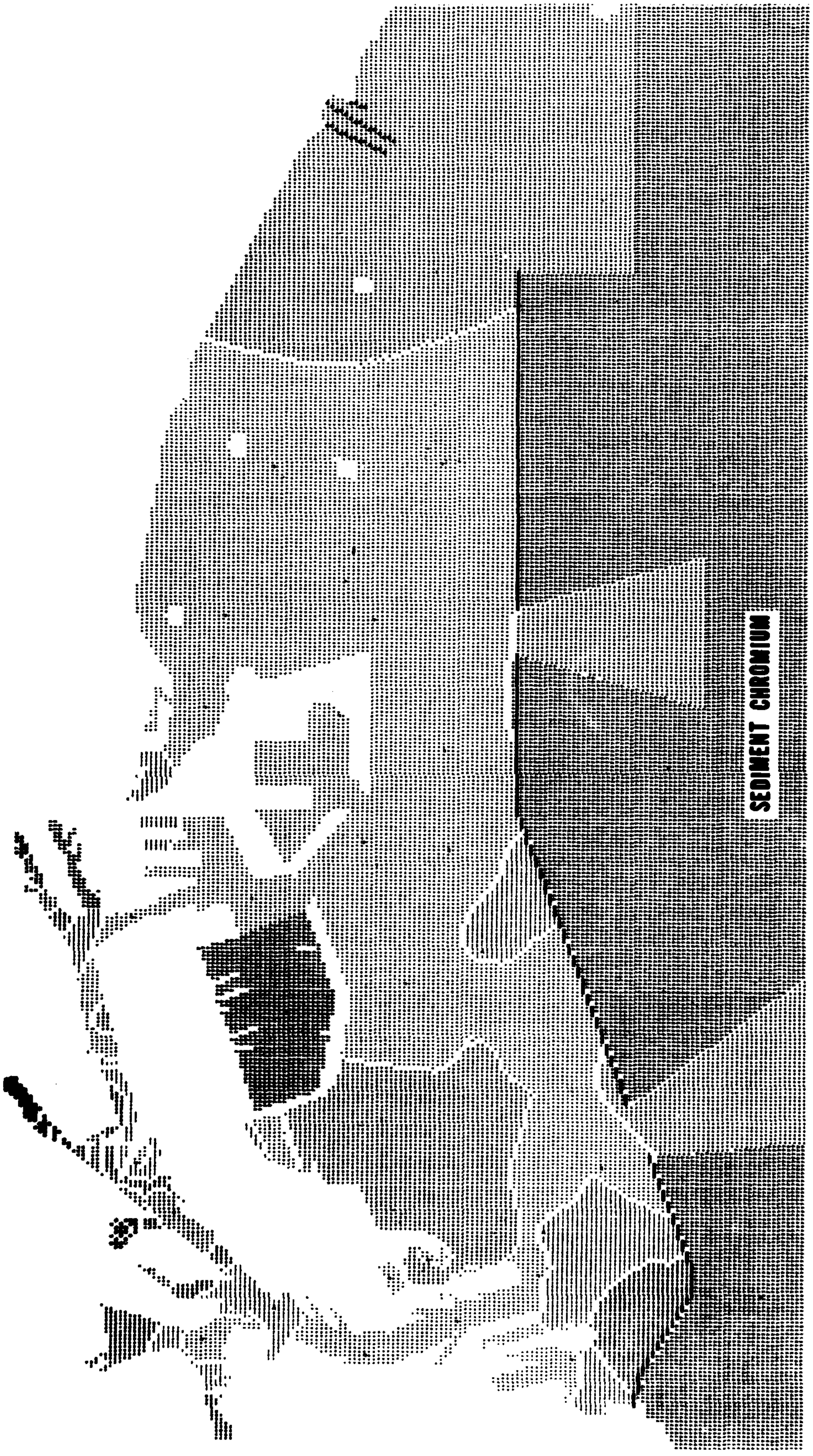


Figure 11.36.

Figure 11.37.
Sediment Copper

```
DATA VALUE EXTREMES ARE        12.00      415.30


TOTAL MISSING DATA POINTS IS        5


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

   MINIMUM     12.00     52.33     92.66    132.99    173.32    213.65    253.98    294.31    334.64    374.97
   MAXIMUM     52.33     92.66    132.99    173.32    213.65    253.98    294.31    334.64    374.97    415.30

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1         2         3         4         5         6         7         8         9        10
           ==========================================================================================================
           .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  ■■■■■■■■■  ■■■■■■■■■  ■■■■■■■■■
           .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  ■■■■■■■■■  ■■■■■■■■■  ■■■■■■■■■
  SYMBOLS  ....1....  ''''2''''  ----3----  ====4====  ++++5++++  XXXX6XXXX  OOOO7OOOO  ■■■■8■■■■  ■■■■9■■■■  ■■■■■■■■■
           .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  ■■■■■■■■■  ■■■■■■■■■  ■■■■■■■■■
           .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  ■■■■■■■■■  ■■■■■■■■■  ■■■■■■■■■
           ==========================================================================================================
  FREQ.          9        15         5         3         1         3         0         0         2         1
         1   I..1..I   I''2''I   I--3--I   I==4==I   I++5++I   IXX6XXI                       I■■9■■I   I■■■■■I
         2   I..1..I   I''2''I   I--3--I   I==4==I             IXX6XXI                       I■■9■■I
         3   I..1..I   I''2''I   I--3--I   I==4==I             IXX6XXI
         4   I..1..I   I''2''I   I--3--I
         5   I..1..I   I''2''I   I--3--I
         6   I..1..I   I''2''I
         7   I..1..I   I''2''I
         8   I..1..I   I''2''I
         9   I..1..I   I''2''I
        10             I''2''I
        11             I''2''I
        12             I''2''I
        13             I''2''I
        14             I''2''I
        15             I''2''I
```

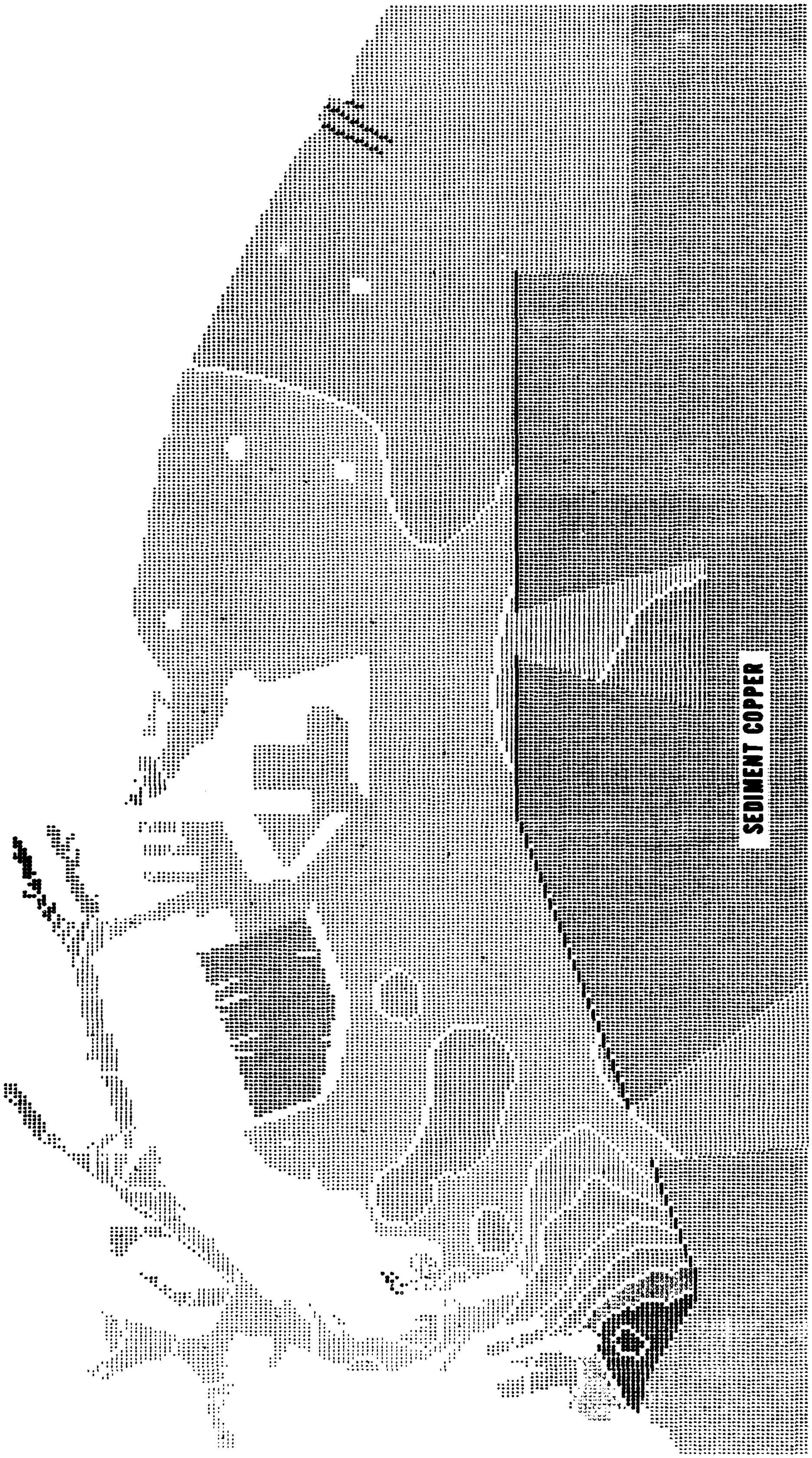


Figure 11.37

Figure 11.38.

Sediment Iron

```
DATA VALUE EXTREMES ARE      10865.00    44665.00


TOTAL MISSING DATA POINTS IS        5


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM  10865.00  14245.00  17625.00  21005.00  24385.00  27765.00  31145.00  34525.00  37905.00  41285.00
  MAXIMUM  14245.00  17625.00  21005.00  24385.00  27765.00  31145.00  34525.00  37905.00  41285.00  44665.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

             10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL        1         2         3         4         5         6         7         8         9        10
          ==========================================================================================================
           .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  ■■■■■■■■■  ■■■■■■■■■  ■■■■■■■■■
           .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  ■■■■■■■■■  ■■■■■■■■■  ■■■■■■■■■
  SYMBOLS  ....1....  ''''2''''  ----3----  ====4====  ++++5++++  XXXX6XXXX  OOOO7OOOO  ■■■■8■■■■  ■■■■9■■■■  ■■■■+■■■■
           .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  ■■■■■■■■■  ■■■■■■■■■  ■■■■■■■■■
           .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  ■■■■■■■■■  ■■■■■■■■■  ■■■■■■■■■
          ==========================================================================================================
  FREQ.        3         3         3         2         5         8         7         3         1         4
         1  I..1..I   I''2''I   I--3--I   I==4==I   I++5++I   IXX6XXI   IOO7OOI   I■■8■■I   I■■9■■I   I■■+■■I
         2  I..1..I   I''2''I   I--3--I   I==4==I   I++5++I   IXX6XXI   IOO7OOI   I■■8■■I             I■■+■■I
         3  I..1..I   I''2''I   I--3--I             I++5++I   IXX6XXI   IOO7OOI   I■■8■■I             I■■+■■I
         4                                          I++5++I   IXX6XXI   IOO7OOI                       I■■+■■I
         5                                          I++5++I   IXX6XXI   IOO7OOI
         6                                                    IXX6XXI   IOO7OOI
         7                                                    IXX6XXI   IOO7OOI
         8                                                    IXX6XXI
```

Figure 11.38

Figure 11.39.
Sediment Mercury

```
DATA VALUE EXTREMES ARE          0.06        4.18


TOTAL MISSING DATA POINTS IS       5


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM      0.06      0.48      0.89      1.30      1.71      2.12      2.53      2.94      3.36      3.77
  MAXIMUM      0.48      0.89      1.30      1.71      2.12      2.53      2.94      3.36      3.77      4.18

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

              10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1         2         3         4         5         6         7         8         9        10

  FREQ.         16         8         9         3         1         1         0         0         0         1
           1  I..1..I  I''2''I  I--3--I  I==4==I  I++5++I  IXX6XXI                                    I##*##I
           2  I..1..I  I''2''I  I--3--I  I==4==I
           3  I..1..I  I''2''I  I--3--I  I==4==I
           4  I..1..I  I''2''I  I--3--I
           5  I..1..I  I''2''I  I--3--I
           6  I..1..I  I''2''I  I--3--I
           7  I..1..I  I''2''I  I--3--I
           8  I..1..I  I''2''I  I--3--I
           9  I..1..I            I--3--I
          10  I..1..I
          11  I..1..I
          12  I..1..I
          13  I..1..I
          14  I..1..I
          15  I..1..I
          16  I..1..I
```

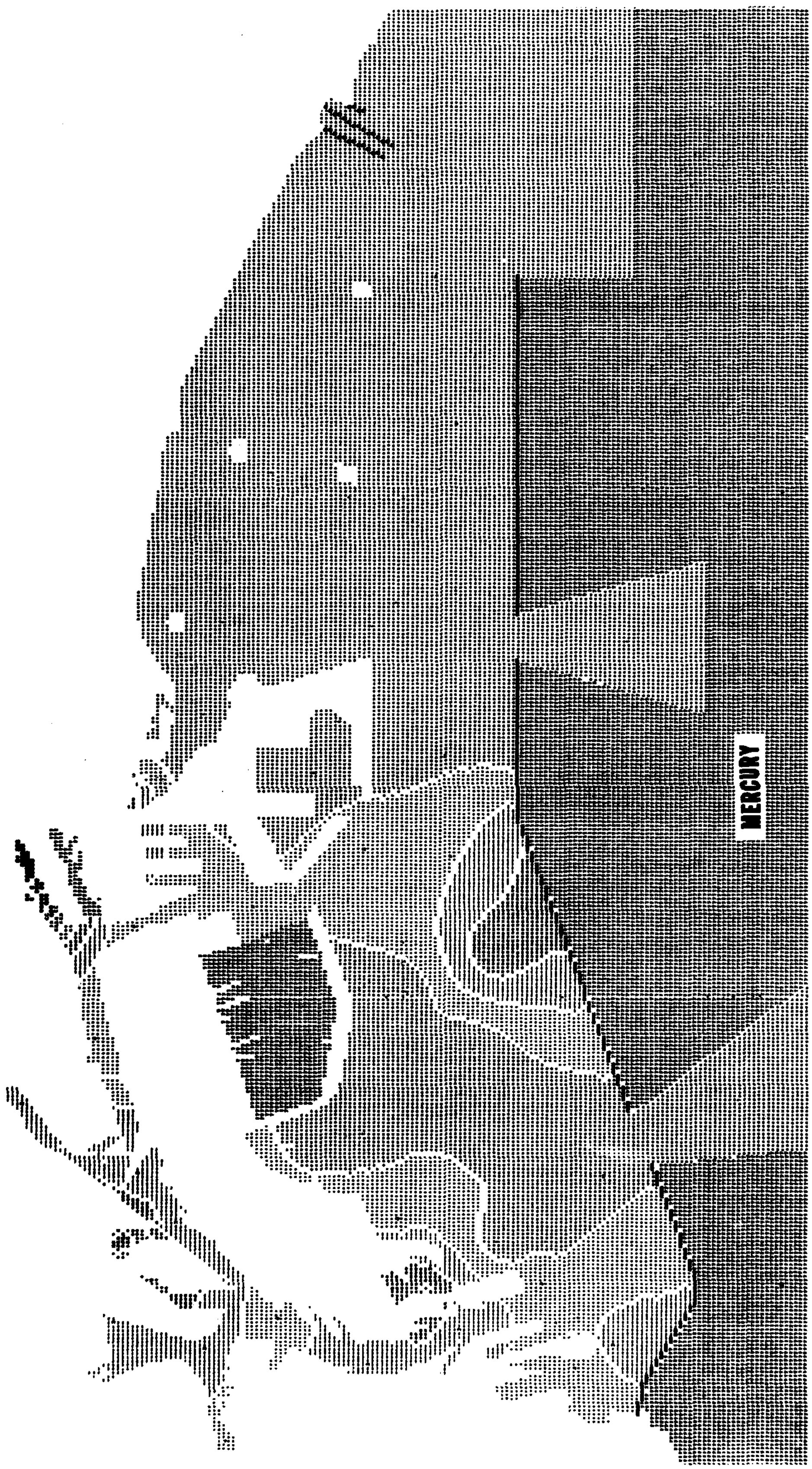


Figure 11.39

Figure 11.40.

Sediment, Oil and Grease

```
DATA VALUE EXTREMES ARE        437.00     5550.50


TOTAL MISSING DATA POINTS IS         5


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM    437.00    988.35   1539.70   2091.05   2642.40   3193.75   3745.10   4296.45   4847.80   5399.15
  MAXIMUM    988.35   1539.70   2091.05   2642.40   3193.75   3745.10   4296.45   4847.80   5399.15   5950.50

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

             10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1         2         3         4         5         6         7         8         9        10
           ======================================================================================================
           .........  .........  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  888888888  999999999  #########
           .........  .........  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  888888888  999999999  #########
  SYMBOLS  ....1....  ....2....  ----3----  ====4====  ++++5++++  XXXX6XXXX  OOOO7OOOO  8888888888 9999999999 #########
           .........  .........  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  888888888  999999999  #########
           .........  .........  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  888888888  999999999  #########
           ======================================================================================================
  FREQ.         10        10         5         4         4         1         2         1         1         1
        1  I..1..I    I..2..I    I--3--I    I==4==I    I++5++I    IXX6XXI    IOO7OOI    I888888I   I889991I   I######I
        2  I..1..I    I..2..I    I--3--I    I==4==I    I++5++I               IOO7OOI
        3  I..1..I    I..2..I    I--3--I    I==4==I    I++5++I
        4  I..1..I    I..2..I    I--3--I    I==4==I    I++5++I
        5  I..1..I    I..2..I    I--3--I
        6  I..1..I    I..2..I
        7  I..1..I    I..2..I
        8  I..1..I    I..2..I
        9  I..1..I    I..2..I
       10  I..1..I    I..2..I
```

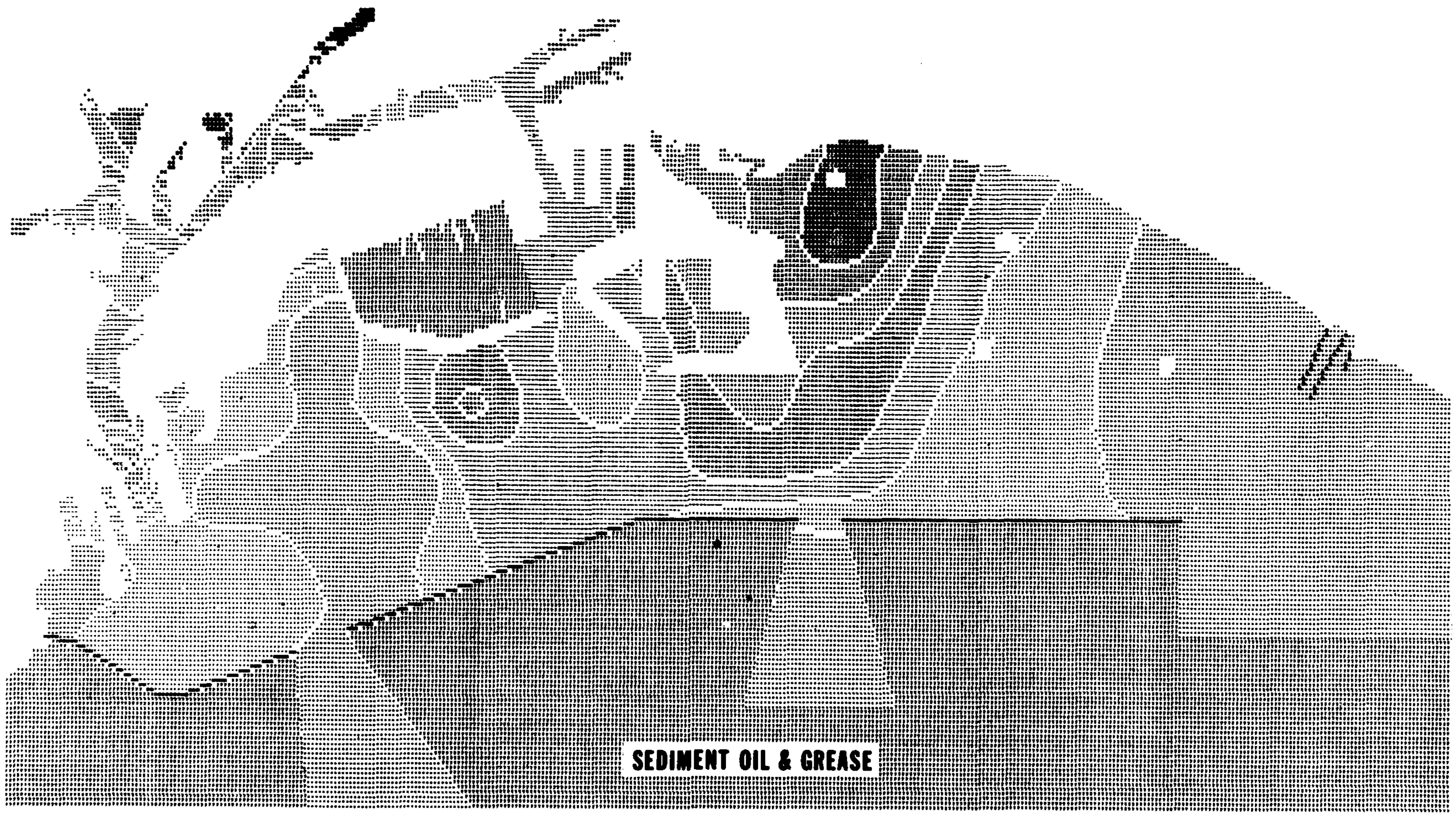


Figure 11.40

Figure 11.41.
Log Sediment Organic Nitrogen

```
DATA VALUE EXTREMES ARE          4.24         8.91


TOTAL MISSING DATA POINTS IS          5


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM      4.24      4.71      5.17      5.64      6.11      6.57      7.04      7.51      7.97      8.44
  MAXIMUM      4.71      5.17      5.64      6.11      6.57      7.04      7.51      7.97      8.44      8.91

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

              10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1         2         3         4         5         6         7         8         9        10
          ==========================================================================================
           .........  ''''''''' --------- ========= +++++++++ XXXXXXXXX 000000000 @@@@@@@@@ ######### #########
           .........  ''''''''' --------- ========= +++++++++ XXXXXXXXX 000000000 @@@@@@@@@ ######### #########
  SYMBOLS  ....1....  ''''2'''' ----3---- ====4==== ++++5++++ XXXX6XXXX 000070000 @@@@8@@@@ ####9#### ####*####
           .........  ''''''''' --------- ========= +++++++++ XXXXXXXXX 000000000 @@@@@@@@@ ######### #########
           .........  ''''''''' --------- ========= +++++++++ XXXXXXXXX 000000000 @@@@@@@@@ ######### #########
          ==========================================================================================
  FREQ.          3         4         8        10         7         6         0         0         0         1
        1   I..1..I   I''2''I   I--3--I   I==4==I   I++5++I   IXX6XXI                               I##*##I
        2   I..1..I   I''2''I   I--3--I   I==4==I   I++5++I   IXX6XXI
        3   I..1..I   I''2''I   I--3--I   I==4==I   I++5++I   IXX6XXI
        4             I''2''I   I--3--I   I==4==I   I++5++I   IXX6XXI
        5                       I--3--I   I==4==I   I++5++I   IXX6XXI
        6                       I--3--I   I==4==I   I++5++I   IXX6XXI
        7                       I--3--I   I==4==I   I++5++I
        8                       I--3--I   I==4==I
        9                                 I==4==I
       10                                 I==4==I
```

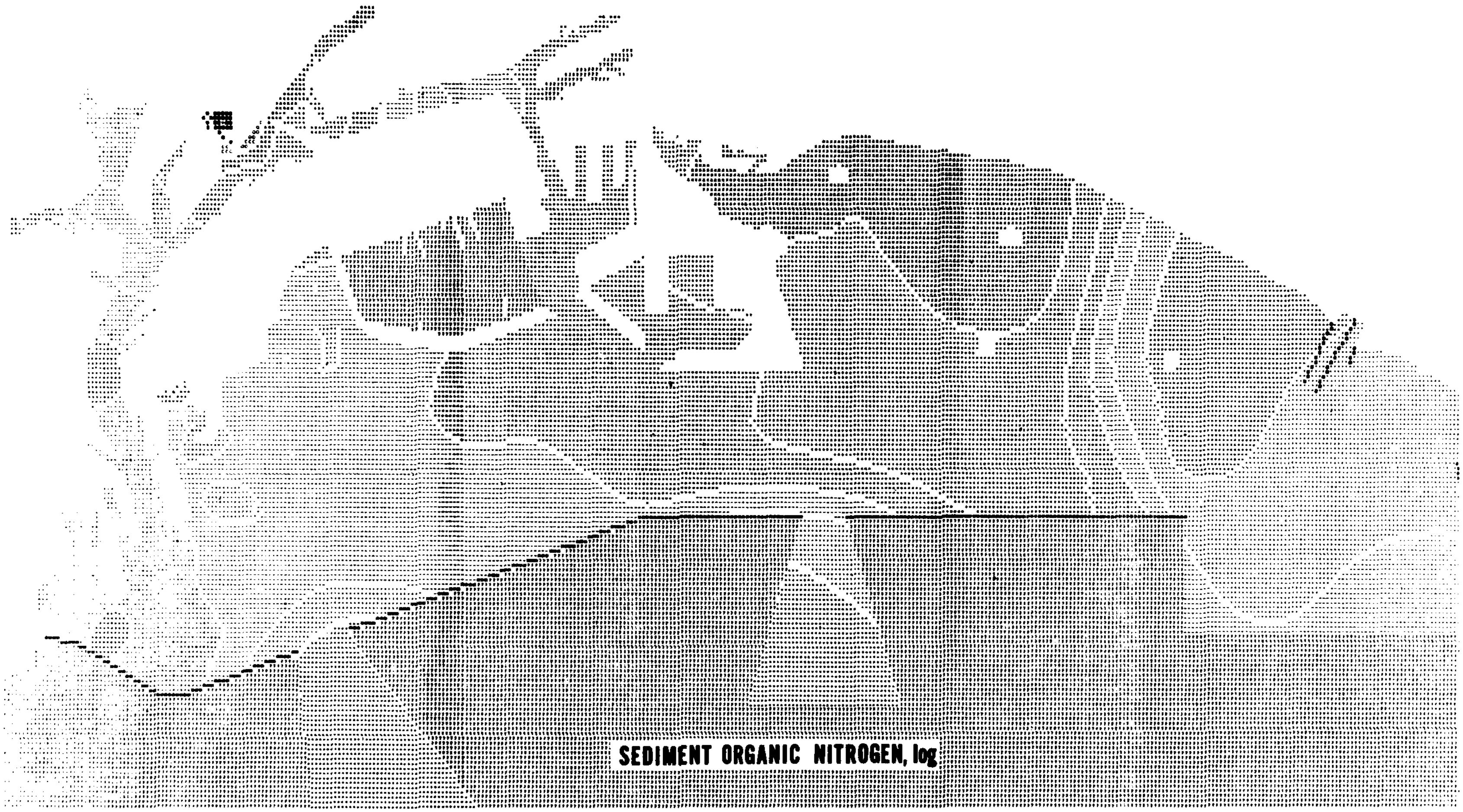


Figure 11.41

Figure 11.42.
Sediment Phosphorus

```
DATA VALUE EXTREMES ARE        818.00     2310.00


TOTAL MISSING DATA POINTS IS        5


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM    818.00    967.20   1116.40   1265.60   1414.80   1564.00   1713.20   1862.40   2011.60   2160.80
  MAXIMUM    967.20   1116.40   1265.60   1414.80   1564.00   1713.20   1862.40   2011.60   2160.80   2310.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

             10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1         2         3         4         5         6         7         8         9        10
          ==============================================================================================
          .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  @@@@@@@@@  @@@@@@@@@  @@@@@@@@@
          .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  @@@@@@@@@  @@@@@@@@@  @@@@@@@@@
  SYMBOLS ....1....  ''''2''''  ----3----  ====4====  ++++5++++  XXXX6XXXX  OOOO7OOOO  @@@@8@@@@  @@@@9@@@@  @@@@*@@@@
          .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  @@@@@@@@@  @@@@@@@@@  @@@@@@@@@
          .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  @@@@@@@@@  @@@@@@@@@  @@@@@@@@@
          ==============================================================================================
  FREQ.          3         6         6         6         9         4         0         1         1         1
         1   I..1..I   I''2''I   I--3--I   I==4==I   I++5++I   IXX6XXI             I@@8@@I   I@@9@@I   I@@*@@I
         2   I..1..I   I''2''I   I--3--I   I==4==I   I++5++I   IXX6XXI
         3   I..1..I   I''2''I   I--3--I   I==4==I   I++5++I   IXX6XXI
         4             I''2''I   I--3--I   I==4==I   I++5++I   IXX6XXI
         5             I''2''I   I--3--I   I==4==I   I++5++I
         6             I''2''I   I--3--I   I==4==I   I++5++I
         7                       I--3--I             I++5++I
         8                       I--3--I             I++5++I
         9                                           I++5++I
```

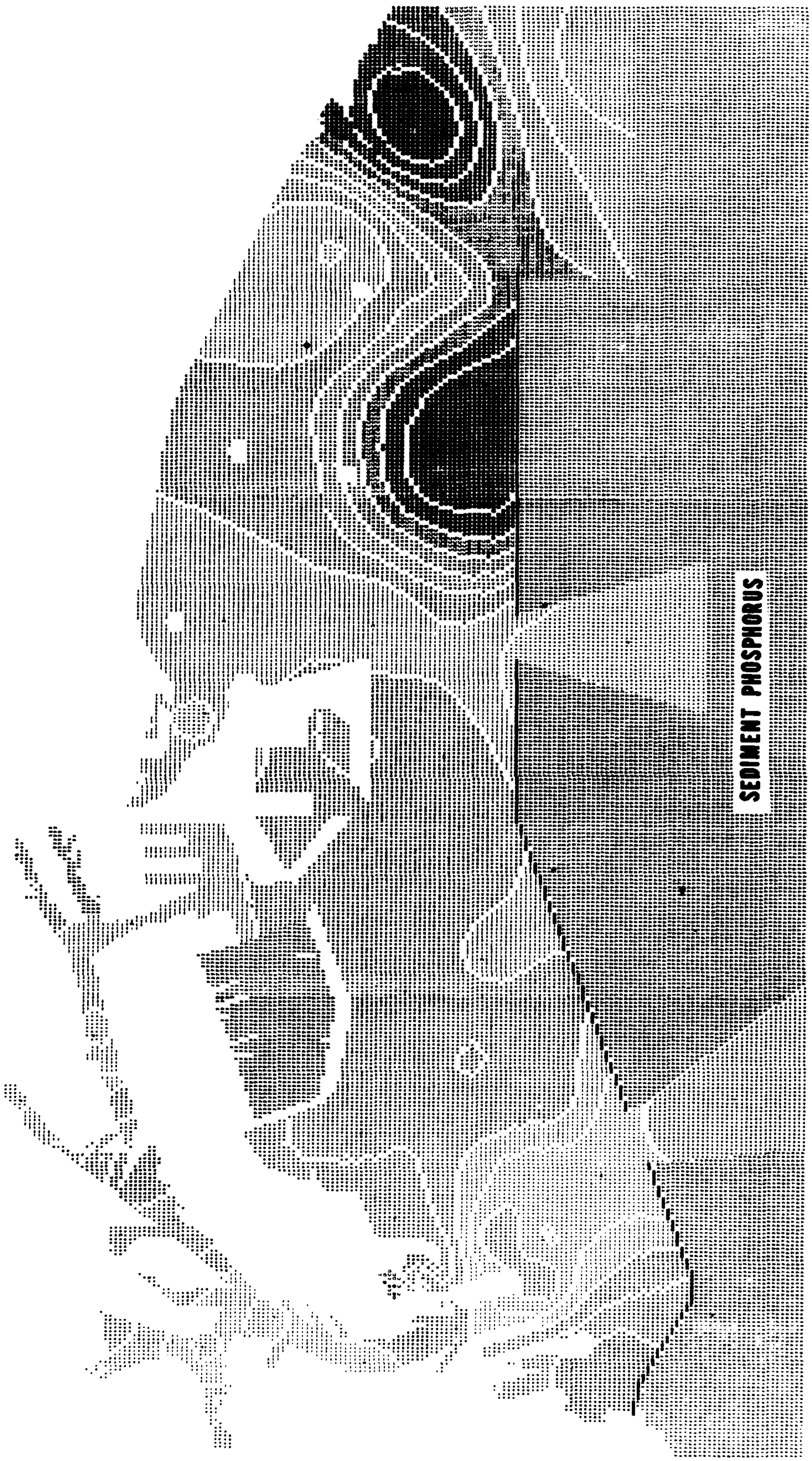


Figure 11.42.

Figure 11.43.

Log Sediment Sulfide

```
DATA VALUE EXTREMES ARE          4.08          8.22


TOTAL MISSING DATA POINTS IS         5


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
       ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM       4.08      4.49      4.91      5.32      5.73      6.15      6.56      6.98      7.39      7.81
  MAXIMUM       4.49      4.91      5.32      5.73      6.15      6.56      6.98      7.39      7.81      8.22


PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00


FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL           1         2         3         4         5         6         7         8         9        10
          ==========================================================================================================
           .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  000000000  @@@@@@@@@  @@@@@@@@@  @@@@@@@@@
           .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  000000000  @@@@@@@@@  @@@@@@@@@  @@@@@@@@@
  SYMBOLS  ....1....  ''''2''''  ----3----  ====4====  ++++5++++  XXXX6XXXX  000070000  @@@@8@@@@  @@@@9@@@@  @@@@*@@@@
           .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  000000000  @@@@@@@@@  @@@@@@@@@  @@@@@@@@@
           .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  000000000  @@@@@@@@@  @@@@@@@@@  @@@@@@@@@
          ==========================================================================================================
  FREQ.          5         1         6         9         5         5         2         2         3         1
        1    I..1..I   I''2''I   I--3--I   I==4==I   I++5++I   IXX6XXI   I007001   I@@8@@I   I@@9@@I   I@@*@@I
        2    I..1..I             I--3--I   I==4==I   I++5++I   IXX6XXI   I007001   I@@8@@I   I@@9@@I
        3    I..1..I             I--3--I   I==4==I   I++5++I   IXX6XXI                       I@@9@@I
        4    I..1..I             I--3--I   I==4==I   I++5++I   IXX6XXI
        5    I..1..I             I--3--I   I==4==I   I++5++I   IXX6XXI
        6                        I--3--I   I==4==I
        7                                  I==4==I
        8                                  I==4==I
        9                                  I==4==I
```

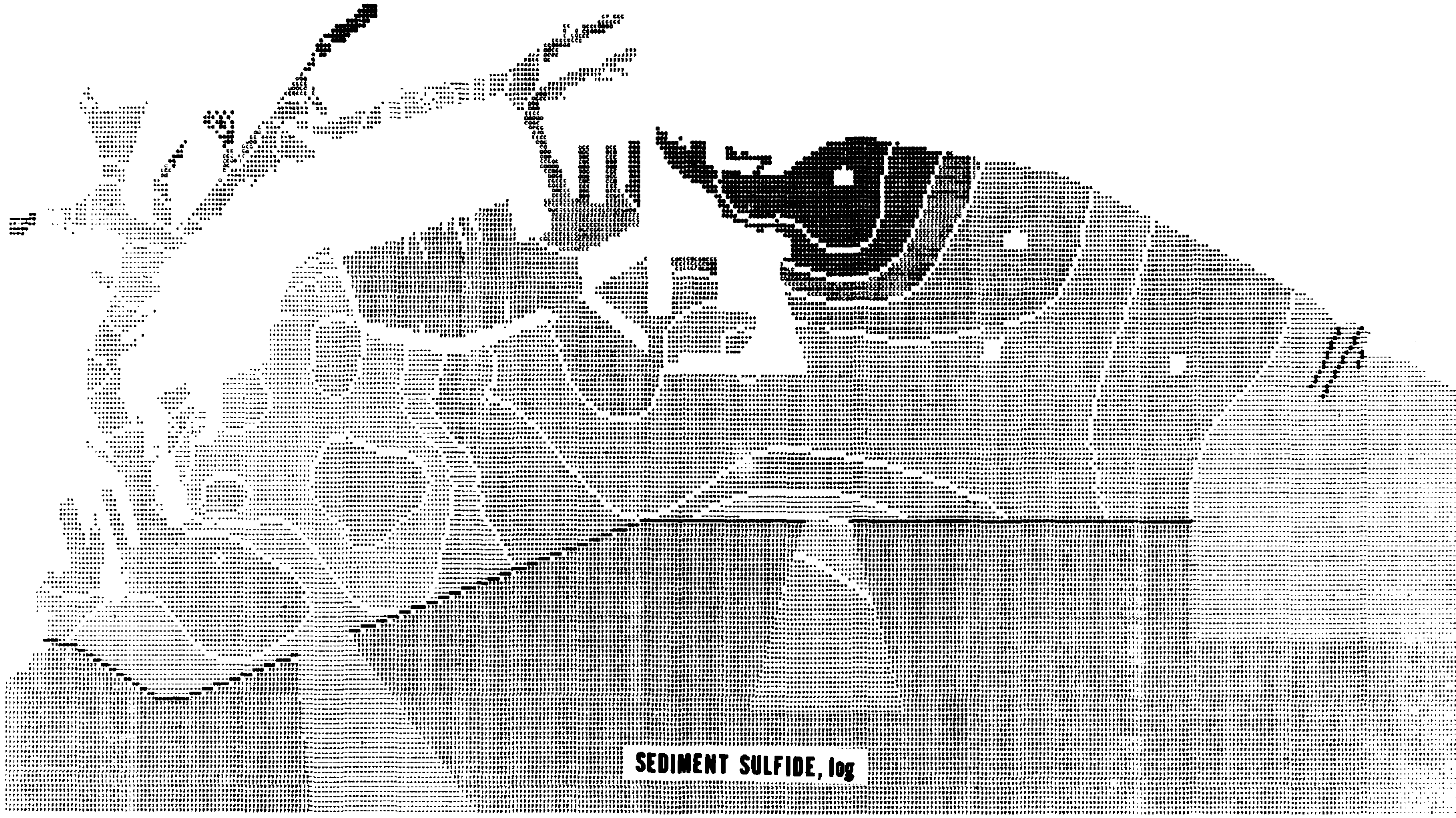


Figure 11.43

Figure 11.44.
Total DDT

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.06	0.30	0.54	0.78	1.02	1.26	1.50	1.74	1.98	2.22
MAXIMUM	0.30	0.54	0.78	1.02	1.26	1.50	1.74	1.98	2.22	2.46

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
FREQ.	13	8	3	3	2	0	0	1	0	1

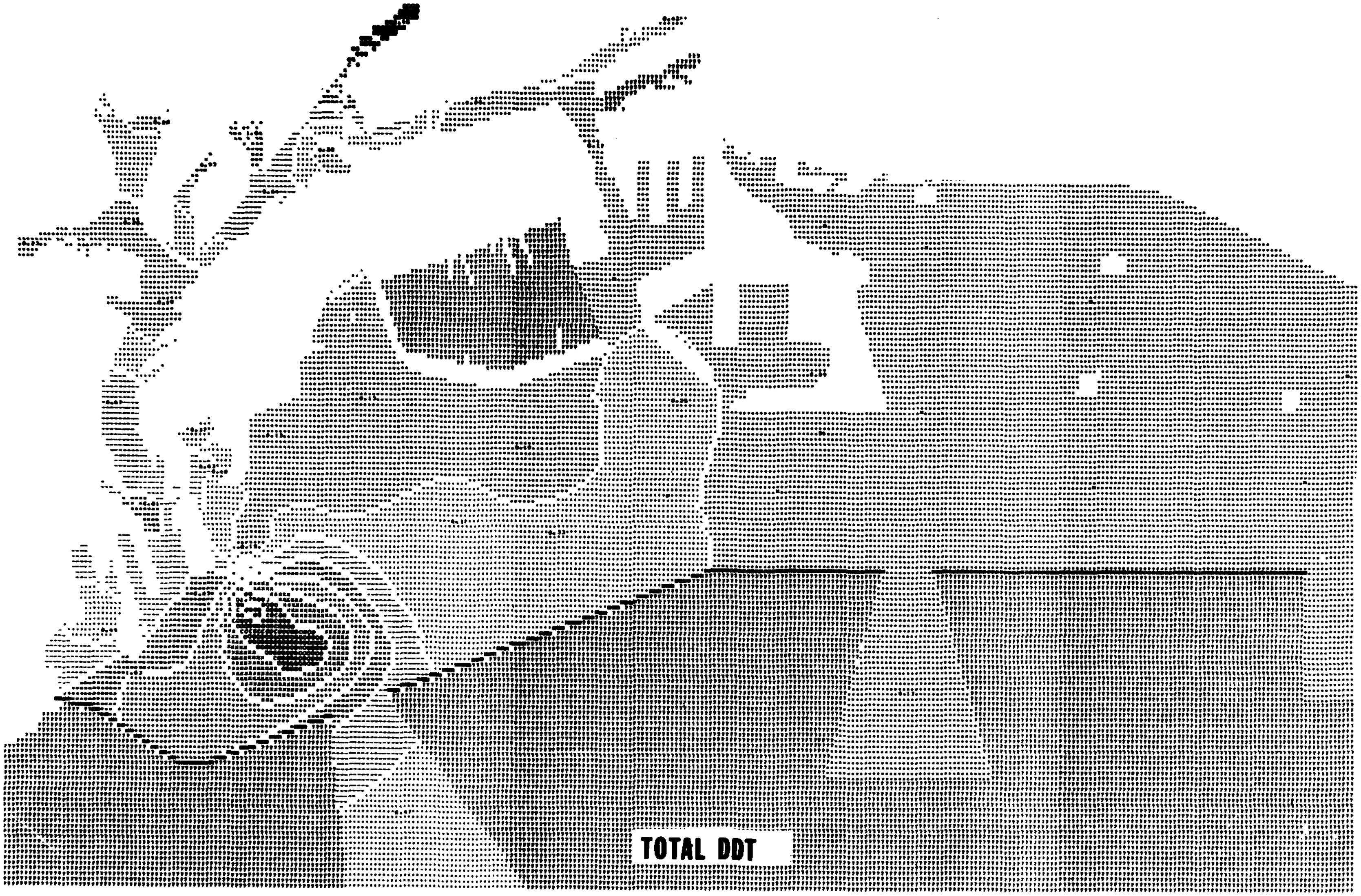


Figure 11.44

Chapter 12

PHYSICAL-CHEMICAL STUDY OF SEDIMENTS FROM THE PROPOSED DREDGING CHANNEL IN THE LOS ANGELES HARBOR

12.1

PHYSICAL-CHEMICAL STUDY OF SEDIMENTS FROM THE PROPOSED DREDGING CHANNEL IN THE LOS ANGELES HARBOR

INTRODUCTION. The potential problems of dredging operations and subsequent disposal of dredge sediments have been delineated in a recent publication of the Army Corps of Engineers (Boyd, et al., 1972). The present studies are intended to seek answers to some of the critical problems that might be encountered in the proposed dredging of the main channel in the Los Angeles Harbor.

The objectives of the physical-chemical study of the abiotic environment of the proposed dredge channel are threefold:

(1) to evaluate the pollutional status of the sediments
(2) to assess the potential water quality effect if the sediment is to be disposed in open waters
(3) to study the methods of mitigation if unfavorable environmental impacts exist.
(4) to determine the relationships with regulatory standards.

In order to achieve these objectives, a series of experiments were carried out. Sediments were characterized in great detail with regard to the composition and concentration of contaminants. Simulated column studies were carried out on the most contaminated sediments in order to evaluate the water quality impact by the open water disposal of dredged spoils. Investigations undertaken cover the migration of trace metals and micronutrients under various environmental conditions, with special emphasis on their short-term effect on water quality. Efforts are made to quantify the amounts of trace metals and nutrients transported as the sediment resuspends and settles in the water column of marine systems.

Additional experiments were carried out to determine the feasibility of direct treatment of dredge spoil in hydraulic pipes before its discharge into a submerged dike area using selective coagulants, to meet the effluent standards of the California State ocean water discharge requirements. The comparison of two types of treatment is discussed for economics and water quality: (a) treatment of returned effluents from diked disposal areas, and (b) direct treatment of the dredged spoil in a hydraulic pipe.

NATURAL SEAWATER AND MARINE SEDIMENTS

The waters of the oceans are a complicated heterogeneous solution, for they contain every naturally occurring chemical element, plus a wide assortment of very complex organic matter. The concentrations of dissolved solids have remained virtually unchanged for the last billion years. Slightly basic, the ocean's pH of about 8.0 does not vary greatly under ordinary marine conditions due to the buffering action of the carbonate system. Surface seawater has an Eh value of +400 mv and the dissolved oxygen (DO) content varies from 5 to 10 mg/l.

Another important source of chemical elements in the sea originates as localized inputs from man's activities, the most common of which come from fossil fuel combustion, mining operations, municipal waste discharge, and industrial sources. Upon reaching the aquatic system, they undergo complex chemical and biochemical interactions. Released in excess of the natural cycling capacity, the trace metals and nutrients accumulate in the sediment, resulting in contamination that may create adverse environmental and ecological impacts.

Fig.12.1 illustrates a typical healthy marine sediment profile showing the chemical and physical changes in the oxidized and reduced layers. Positive Eh represents well-oxygenated sediments, coarse in grain size and poor in organic matter, while negative Eh characterizes fine organic-rich sediments. Bottom deposits from the coast of California range from pH 7.0 to 8.5 with an Eh range of +0.35 to -0.50 volts (Zobell, 1946). Fig.12.2 outlines the limits of pH and Eh for seawater and sediment found under natural conditions (Krauskopf, 1967; Bass-Becking, et al., 1968). A straight line from Eh 0.2 at pH 2 to Eh -0.2 at pH 10 marks the boundary between oxidizing and reducing environments.

The purpose of this presentation is to compare the conditions of sediments existing in the proposed channel. A substantial difference from the normal, healthy sediment type in an uncontaminated area will reflect the degree of man-made contamination. The disposal of contaminated sediments will require careful evaluation of potential environmental impacts.

Marine Sediment Profile

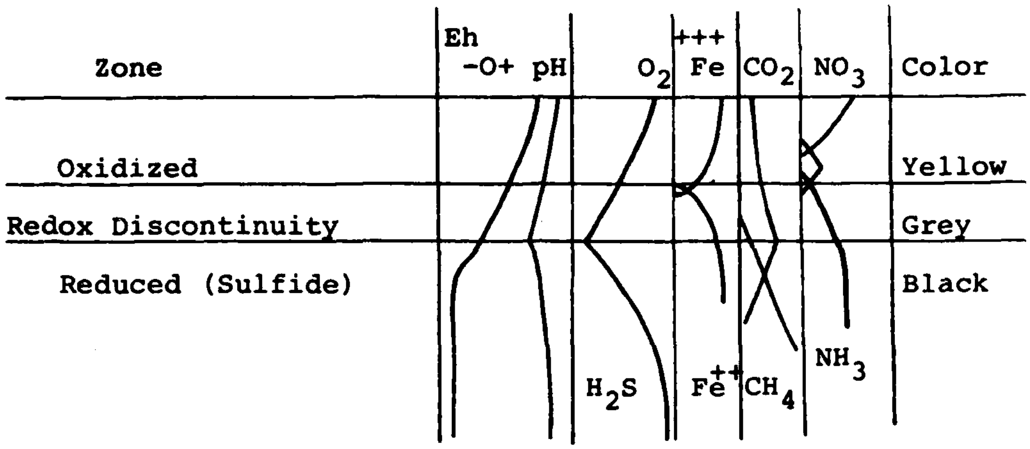


Figure 12.1. Marine sediment profile showing the Eh (redox potential) and pH profiles, and the vertical distribution of some compounds and ions. The redox potential is minus in the reduced zone, 0 to +200 millivolts in the discontinuity transition region, and above 200 in the fully oxidized zone (Odum, 1971).

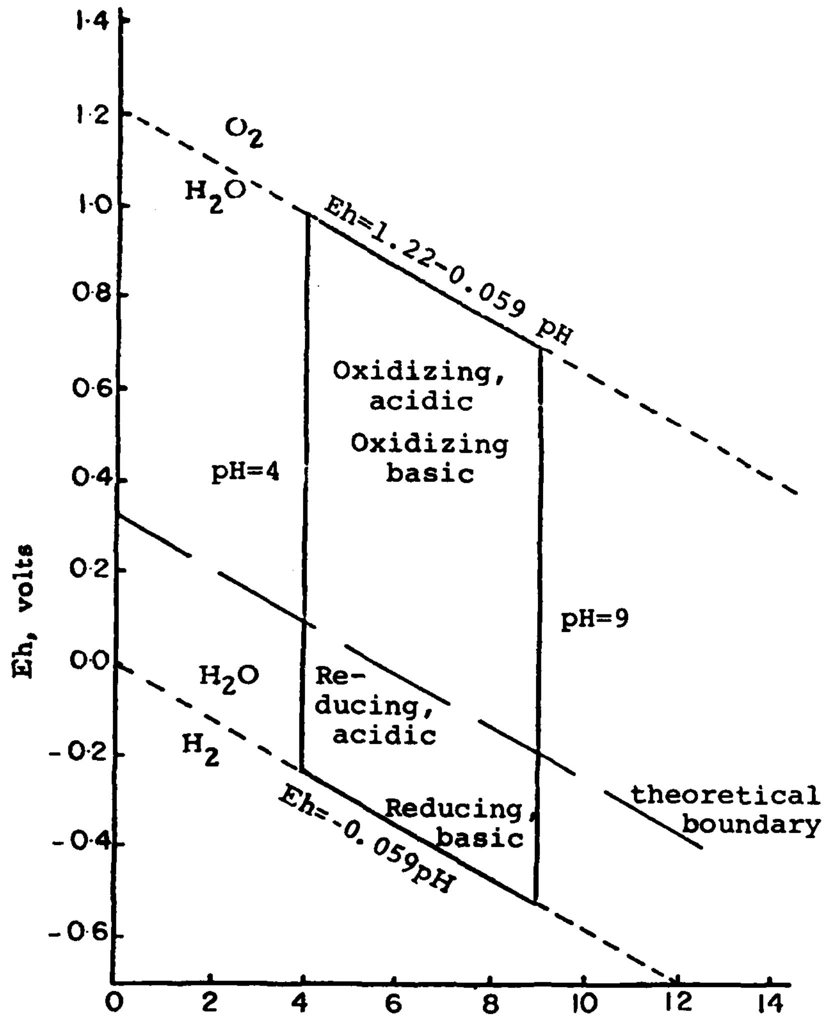


Figure 12.2. Eh and pH Limits in Natural Environments. (Krauskopf, 1967)

CHARACTERIZATION OF SEAWATER AND SEDIMENT SAMPLES FROM THE PROPOSED DREDGING CHANNEL

Seawater and sediment samples used in the experiments were collected from the proposed dredging channel by the personnel of the Harbor Environmental Projects of the Allan Hancock Foundation during weekly cruises on board the ocean-going vessel Velero IV. Seawater samples were collected in acid-cleaned 5-gallon polyethylene containers. The capacity of certain container surfaces to adsorb trace metal ions from seawater has been pointed out by Robertson (1968). Therefore, seawater samples were generally utilized within 48 hours after collection.

Physical-chemical properties of the sediment samples were characterized with respect to trace metals, nutrients, and other chemical constituents. Table 12.1 shows chemical properties and composition of the different sediment samples. Station A5 and C8 sediments are classified as organic and sulfide-rich, and are the most contaminated, showing high values for most of the constituents (see pp. 12.30-12.33).

Interstitial water analysis, Table 12.2, reveals that Fe, Mn, and occasionally Zn are several orders of magnitude higher than in the overlying waters. Brooks, et al. (1968) and Presley, et al. (1972), found similar enrichment in the interstitial waters. Lee and Plumb (1974) summarized the literature on leaching of 16 metals from sediments. Factors causing high soluble metal concentrations at the surface of sediments are: (a) biochemical activity of organisms, (b) high concentrations of chloride in seawater, (c) effects of metal complexes, and (d) possibly, the influence of polysulfides.

The excessively high concentrations of sulfide in the surface sediments differ greatly from the profile shown in Figures 12.1-12.2. In most cases, surface sediments are in reduced states. Obviously, a careful evaluation of the water quality impact is needed.

EXPERIMENTAL PROCEDURES.

Evaluation of Water Quality Effects in Simulated Conditions.

A. Column Design and Procedures

Two specially designed settling columns were used in

Table 12.2

Interstitial Water Analysis

Station	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
A5	0.4	0.4	0.5	170	10.0	0.9	0.5	16
C8	0.5	0.6	0.5	160	8.0	0.7	0.6	15

Concentrations in µg/l

Ranges: Background Seawater	0.03-0.24	0.05-0.8	0.1-0.8	0.4-3.0	0.4-3.0	0.02-.75	0.03-0.12	0.2-0.5

the column studies. A diagram is shown in Figure 12.3.

The basic procedures for the resuspension of sediment in the water column may be described as follows:

(1) Assemble and clean column by soaking overnight with 5% HCl.

(2) Rinse thoroughly with distilled water.

(3) Fill with water and pre-treat by bubbling gas, if necessary.

(4) Under a glove bag purged with nitrogen gas, measure out 4 liters of sediment.

(5) Mix thoroughly with 16 liters of pre-treated water.

(6) Remove from glove bag and immediately pour mixture into the column to make a 1:20 ratio.

(7) Introduce agitation by bubbling gas through holes at the lower portion of the column.

(8) Withdraw samples from column with 50 ml B-D Plastipak syringes at regular intervals.

(9) Filter through 0.2 µm Millipore membrane filter to remove colloidal and suspended particles.

(10) Collect samples in pre-cleaned bottles.

(11) Fix samples with necessary reagents and store in a dark, cool place until needed.

B. Test Parameters

The variables of the simulated column studies are: (a) type of sediment, (b) type of water, (c) initial dissolved oxygen content, and (d) agitation. Depending on the initial D.O. and the type of agitation provided, the test conditions were grouped into types as listed in Table 12.3.

C. Sampling and Analysis

Samples were taken at 0, 1/2, 1, 2, 4, 8, 12, 24, and 48 hour intervals and collected in clean plastic bottles, after which the necessary reagents were added immediately to preserve the sample.

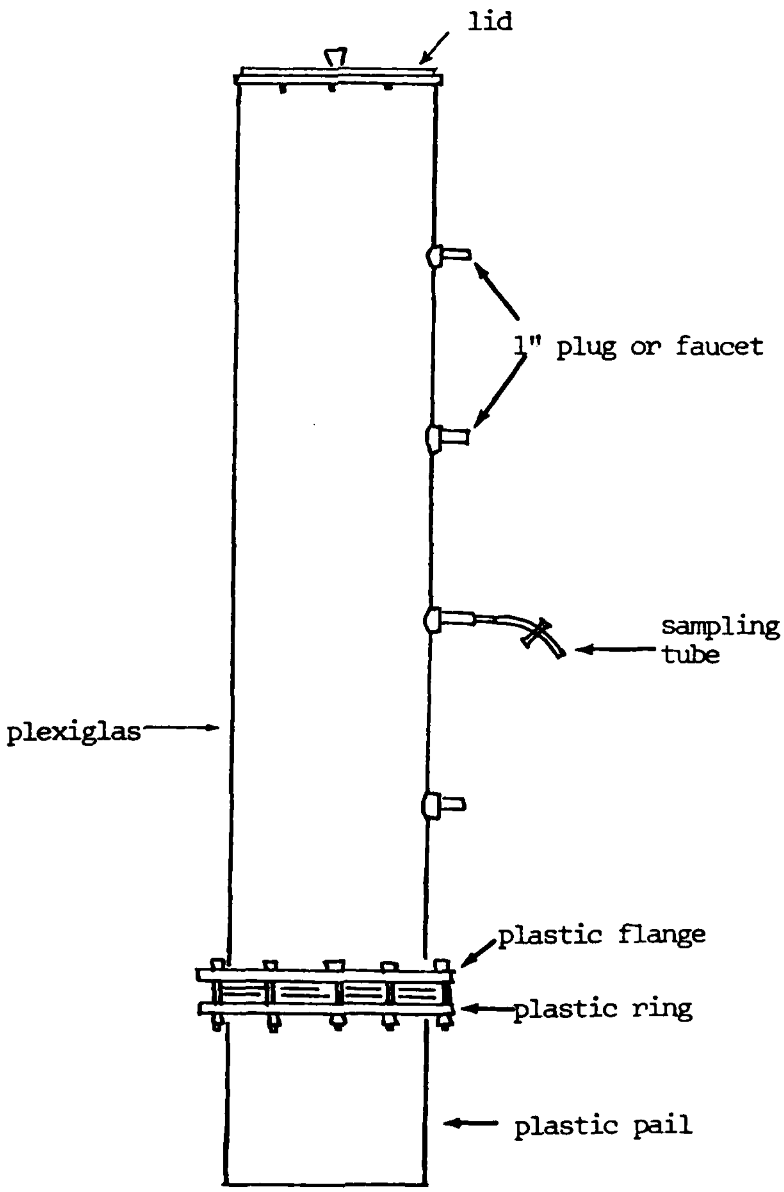


Figure 12.3
Schematic diagram of the settling column.

Table 12.3 - Column Test Conditions

Type	Seawater Pre-treatment	Form of Agitation
A	none	quiescent
B	nitrogen	quiescent
C	oxygen or compressed air	quiescent
D	nitrogen	nitrogen bubbling
E	compressed air	compressed air bubbling

The samples were analyzed for pH, temperature, D.O., total sulfide, nitrogen (Kjeldahl, ammonia, and organic), phosphate (total and orthophosphate), silica, and heavy metals (Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, and Zn). All of the analytical procedures adopted, except those for heavy metals which are found in the Appendix, are described in the Standard Methods for the Examination of Water and Waste-Water, 13th ed. (1971).

D. Column Test Runs

A total of 10 column test runs were completed. Table 12. 4 lists the conditions under which the experiments were conducted.

Treatment of Dredged Spoils.

A. Jar Test for Optimum Dosage

Two selected polymers, one cationic polymer CAT-FLOC T, and one anionic polymer WT-3000, were found in preliminary screening tests to be the most effective coagulants. These were used to evaluate the optimum dosage.

The standard jar tests were performed using a multiple stirring apparatus equipped with 1" x 3" stirrers and a variable speed mixing control. The basic procedures for jar tests may be described as follows:

(1) Place 150 ml sediment and 600 ml seawater in a 1-liter beaker (prepare 6 samples for one group).

(2) Mix at 80 rpm for 5 minutes to homogenize the mixture.

(3) Add a desired dosage of polymer to each beaker and mix for 5 minutes at 100 rpm.

Table 12.4

Column Test Runs

Col. Test Series	Type	Sta. No.	Seawater Pre-treatment	D.O.	pH	Condition after add. of mixture
I	A	A5	None	7.0	7.5	Quiescent
II	B	A5	Nitrogen	0.35	7.8	Quiescent
III	C	A5	Compressed air	7.0	8.0	Quiescent
IV	D	A5	Nitrogen	0.2	8.43	Cont. Agitation
V	E	A5	Compressed air	6.6	7.75	Cont. Agitation
VI	A	C8	None	7.2	7.8	Quiescent
VII	B	C8	Nitrogen	0.3	8.0	Quiescent
VIII	C	C8	Compressed air	7.6	8.15	Quiescent
IX	D	C8	Nitrogen	0.3	8.61	Cont. Agitation
X	E	C8	Compressed air	6.8	7.87	Cont. Agitation

(4) Reduce the mixing rate to 20 rpm and continue mixing for 20 minutes.

(5) Let stand for 10 minutes to settle the floc.

(6) Withdraw samples from each beaker with gentle suction from a fixed point.

(7) Determine turbidity and suspended solids.

B. Column Design and Procedures

The column design and flow chart for the simulated experiment of the dredge spoils disposal are shown in Figure 12.4. The basic procedures for flocculation are as follows:

(1) Mix sediment and seawater at a 1:4 ratio in a 2-liter polyethylene container.

(2) Add the optimum dosage of polymer to the above mixture (10 - 15 ppm, as shown in Table 12.25).

(3) Shake vigorously for 5 minutes and pour immediately into the water column, to a final sediment-seawater ratio of approximately 1:100.

(4) Withdraw the samples with 50 ml plastic syringes at regular intervals.

(5) Pass through 0.45 μm Millipore membrane filter to remove colloidal and suspended particles.'

(6) Collect samples in pre-cleaned bottles.

C. Sampling and Analysis

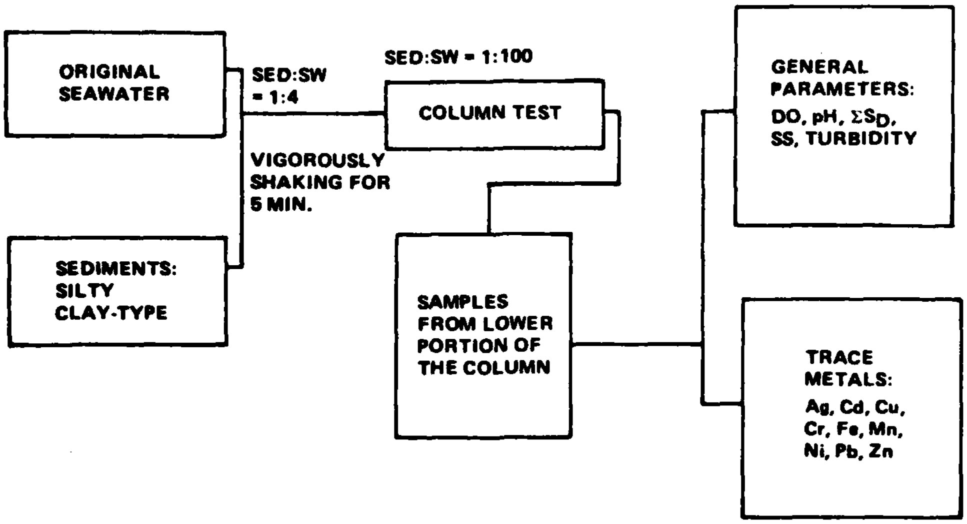
Samples were taken at intervals of 5 minutes and at 1/2, 1, 2, 4, 24, 48, and 78 hours, and collected in clean plastic bottles, after which the necessary reagents were immediately added to preserve the sample.

The samples were analyzed for pH, D.O., dissolved sulfide, suspended solids, turbidity, total trace metals, and chlorinated hydrocarbons.

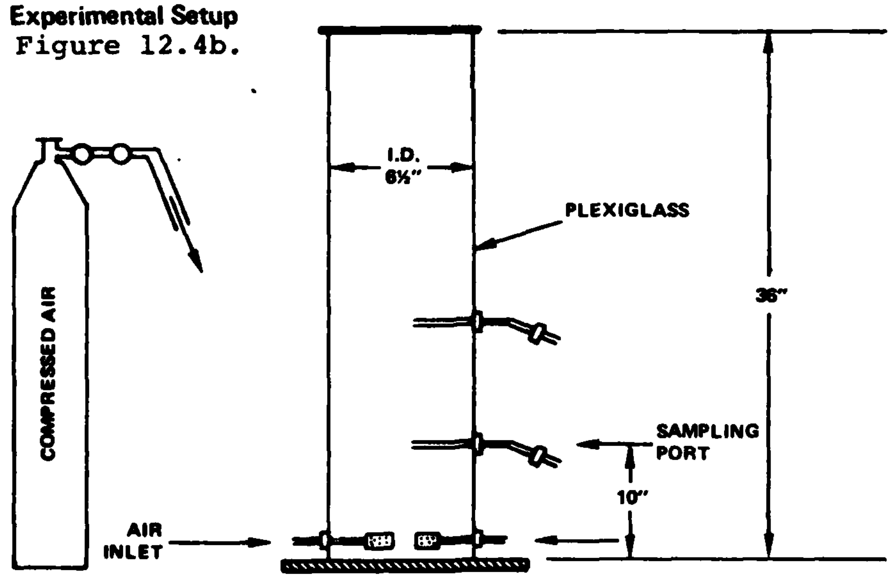
ANALYTICAL DETERMINATION OF TRACE METALS IN SEAWATER

Conventional methods for water analysis did not prove suitable for seawater. Besides low concentrations of heavy metals, problems encountered were: (a) the presence of interfering ions (alkaline earth and alkali elements), (b) the ease of introduction of contaminants, (c) the reduc-

Figure 12.4a



Experimental Setup
Figure 12.4b.



Source: Chen and Lu, 1974

FIGURE 12.4

FLOW CHART OF COLUMN TEST AND EXPERIMENTAL SETUP

tion in analytical sensitivity due to matrices present, (d) adaptability to multi-element determination, and (e) preparation of ppb-range standard solutions.

A Perkin-Elmer Atomic Absorption Spectrophotometer Model 305B equipped with heated graphite atomizer Model 2100 and deuterium arc background corrector was used for metal analysis because of its high sensitivity, selectivity, speed, and efficiency of operation. The techniques for sample preparation and method of introduction into the equipment vary according to the method used. The three methods utilized are as follows:

Method	Element
1. Direct injection	Cr, Fe, Mn
2. APDC-MIBK extraction	Ag, Cd, Cu, Ni, Pb, Zn
3. Flameless atomic absorption	Hg

Cr, Fe, and Mn analytical responses in seawater have sufficient sensitivity to be determined by direct injection (Segar and Gonzalez, 1972; Willey, et al., 1972; Segar, 1971) with the aid of the D_2 arc background corrector to reduce interferences from salt volatilization. The concentrations of the other elements must be raised to levels within the sensitivity of the AA spectrophotometer. Many procedures have been described (Riley and Taylor, 1968; Joyner, 1967; Dyrssen, 1972) for pre-concentration of the metal ions, but the most common method employs the simultaneous extraction of the metal complexes with ammonium pyrolidine dithiocarbamate (APDC) into methyl isobutyl ketone (MIBK)--referred to here as APDC-MIBK extraction. Mercury was rendered volatile by reducing the mercuric species in solution with stannous chloride and stripping with nitrogen gas (Willey, et al., 1972; Omang, 1971; Hatch and Ott, 1968). The vapor passes through the absorption cell and registers as output on the recorder.

Numerous hours of preliminary work were devoted to obtaining the optimum operating conditions on the Perkin-Elmer AA Spectrophotometer Model 305B. Slight modifications in setting were made over the manufacturer's recommendations, because the sensitivity of some elements was such that a slight readjustment in setting would result in major changes in peak height and characteristics. The sample injection size was kept at 10 µl.

Table 12.5 shows optimum operating temperature and

Table 12.5

Optimum AA Spectrophotometer Settings
(Temperature in ^{o}C, Time in Sec.)

	Ag	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
Wavelength, nm	328.1	228.8	357.9	324.7	248.3	253.7	279.5	232.0	283.3	213.9
Drying Temp.	125	125	125	125	125		125	125	125	125
Drying Time	20	30	30	20	20		20	20	30	20
Charring Temp.	650	400	1250	950	1250		1100	1200	550	500
Charring Time	30	30	45	30	60		50	40	40	50
Atomizing Temp.	2400	1550	2600	2550	2400		2400	2550	2000	2000
Atomizing Time	8	8	6	8	7		5	7	7	6

time for each element, based on the preliminary investigations.

RESULTS AND DISCUSSION.

Resuspension Studies. Results of the individual trace metal and nutrient analyses of the 0.2 µm-filtered samples are tabulated as a function of time in Tables 12.6-12.15. Discussion of the effects and reactions will be limited to major mechanisms due to the wide diversity and complexity of seawater-sediment interactions. (see pp. 12.34 to 12.43).

Dissolved Oxygen. Upon the addition of the seawater-sediment mixture (1:4 ratio) to the seawater column, the D.O. immediately drops to a much lower level with organic and sulfide-rich sediment. As seen in Table 12.16 shows the Types A and C tests recover slightly with time, while Types B and D tests drop to virtually zero, due to the high initial oxygen demand of the sediments and the low initial D.O. content of the water. Continual bubbling of compressed air (Type E) permits the D.O. to recover to its original level within 2 - 4 hours. Results of a separate bench test shown in Table 12.17 indicate that the most contaminated sediments (Station C8) have the highest oxygen uptake rate. An increase in the seawater:sediment ratio can prevent the abrupt initial D.O. drop to a substantial degree.

In the presence of oxygen, the lower outputs of soluble Fe indicate the formation of the insoluble species of hydrous Fe oxides.

The oxygen concentration determines the chemical form of an element, ultimately influencing the migration of its ions. Possible reactions involved in the oxidation of iron sulfide and some pertinent information on the sulfide mechanism in anaerobic sediments may be summarized as shown below.

The oxidation of sulfides may be accelerated considerably in the presence of transition metals as catalysts (Chen, 1972, 1974).

$$2FeS_2 + 2H_2O + 7O_2 \longrightarrow 2FeSO_4 + 2H_2SO_4$$

$$12FeSO_4 + 3O_2 + 36H_2O \longrightarrow 4Fe_2(SO_4)_3 \cdot 9H_2O + 2Fe_2O_3$$

$$FeSO_4 + 2H_2O \longrightarrow Fe(OH)_2 + H_2SO_4$$

$$Fe(OH)_2 + O_2 + 2H_2O \longrightarrow 4Fe(OH)_3$$

Table 12.16

Dissolved Oxygen in the Settling Column

All units in mg/l.

	Type A		Type B		Type C		Type D		Type E	
Station	Init.	Range	Init.	Range	Init.	Range	Init.	Range	Init.	Range
A_5	7.0	0-0.1	0.35	0.0	7.2	0-0.1	0.2	0-0.1	6.7	0.4-6.7
C_8	7.2	0-0.1	0.30	0.0	7.6	0-0.1	0.30	0-0.1	6.8	0.3-6.7

Table 12.17

Oxygen Uptake Rate of Different Sediment Types

Station	Type of Sediment	Moisture Content %	Wet Density (g/ml)	Sediment-Seawater (by vol.)	Initial D.O. drop mg/l (30 sec.)	Oxygen Uptake Rate (mg/l/hr)
				1/100	4.30	0.05-1.2
C_1		21.94		1/150	2.80	0.10-1.2
				1/300	1.45	0.05-1.2
				1/100	5.70	0.05-1.2
C_8		56.72		1/150	4.00	0.05-1.5
				1/300	2.35	0.10-1.8

$$2Fe(OH)_3 \longrightarrow Fe_2O_3 \cdot H_2O + 2H_2O$$

$$FeS_2 + H_2SO_4 \longrightarrow FeSO_4 + H_2S + S$$

$$2H_2S + O_2 \longrightarrow 2H_2O + S$$

The absence and presence of the dissolved oxygen has been used as the basis for predicting the redox condition, inasmuch as Eh measurements do not reflect the actual reaction but rather the measurement of mixed potential.

Temperature. All column tests were performed at room temperature. The seawater temperature fluctuated between 1 and 2°C, and no observable effect was attributed to this small change. Temperature change generally affects the solubility of metals, silica in particular.

pH. Despite the small variation in pH, a pattern associated with the quiescent and non-quiescent environment may be generalized as follows: Type A, B, and C (quiescent settling conditions) tend to show a small decline in the final pH; Type D and E (agitated settling conditions) indicate a slight increase in pH value with time. A reduction in pH generally indicates an increase in the solubility of certain metals.

Sulfide. Column tests using the most contaminated sediments showed the highest sulfide release, with the quiescent tests releasing more than the agitated tests. The presence of sulfide would create a reducing environment, resulting in the lowering of pH. However, in agitated tests, the overall pH tends to show a slight increase. This may be due to the immediate outflow of released sulfide from the agitated water system.

Quiescent and Agitated States. Normally, a high degree of agitation induces a more rapid transfer of solutes from the solid phase. Under quiescent conditions, an oxidizing environment (for Hg and Pb) and a slightly reducing environment (Fe and Ni) produced a larger release of the indicated metals than that under constant agitation. The high Zn content in the agitated anaerobic state may be due to contamination.

Trace Metals. Most of the trace metals displayed a release pattern immediately after the addition of the sediment mixture to the seawater. A sudden release of metal to the seawater during the first hour was followed by subsequent removal from solution--gradually, as in slightly reducing environments; or immediately, under slightly oxidizing to

oxidizing environments.

During the resuspension of sediments in seawater, numerous forms of interactions occur between ions, solution, and solids, or a combination of two or more forms, resulting in a net transfer of metal ions through the sediment-seawater interface. The turbulent mixing during the introduction of the sediment mixture promotes the release and diffusion of metals from the enriched interstitial water found in reduced sediments. Upon release and exposure to oxygen, the metals may:

(1) readsorb to the organic matter (Lee and Plumb, 1974; Chen, 1974; Siegel, 1971; Gibbs, 1973; Rubin, 1975; Stumm and Morgan, 1970; Armstrong, et al., 1966; Blum, et al., 1974)
(2) adsorb primarily to Fe and Mn oxides (Gibbs, 1973; Rubin, 1975; Bear, 1964; Moore, 1963; Nair and Cottenie, 1971; Gardiner, 1974; Windom, 1972; Krauskopf, 1956; Jenne, 1968; Argaman and Weddle, 1973; Wakeman, 1974)
(3) precipitate (Lee and Plumb, 1974; Gibbs, 1973; Rubin, 1975; Stumm and Morgan, 1970; Bear, 1964; Gardiner, 1974; Windom, 1972; Krauskopf, 1956)
(4) co-precipitate (Gibbs, 1973; Rubin, 1975; Stumm and Morgan, 1970; Windom, 1972; Krauskopf, 1956; Jenne, 1968)
(5) form complex metal compounds (Lee and Plumb, 1974; Chen, 1974; Gibbs, 1973; Rubin, 1975; Stumm and Morgan, 1970; Bear, 1964; Jenne, 1968; Argaman and Weddle, 1973)
(6) incorporate into living organisms (Lee and Plumb, 1974; Stumm and Morgan, 1970; Krauskopf, 1956; Argaman and Weddle, 1973).

Aside from C, N, and O, three active elements predominantly found in sediments--Fe, Mn, and S--play active roles in the redox reactions.

Two other possible mechanisms of removal of metals from the seawater may be (a) precipitation of sulfides under reducing conditions, and (b) biological processes. Among other interactions which may occur simultaneously, some of which are complex and diversified, transition metals are also known to be catalysts in accelerating Fe reactions.

Almost all the heavy metals showed varying degrees of release from the sediment, but the raw data did not show distinct patterns to provide a generalized trend. In certain test types, the D.O. and sulfide configuration changed entirely, due to the varying sediment characteristics, dras-

tically altering the redox environment. Other possible causes for erratic results may be contamination and loss by adsorption to column or containers.

In the short-term study (72 hr period), the concentration factor for each metal species calculated from the areas on the time-concentration graphs enables the comparison of the relative degree of release for each metal. Table 12.18 tabulates the metal release factor for each metal and test type relative to the seawater background. The release phenomena may be classified as:

(a) metals most significantly released (factor 10-160) --Fe, Mn, and Ni

(b) metals moderately released (factor 3.4 to 17.5) --Cr, Cu, Pb, and Zn

(c) metals showing negligible release--Ag, Cd, Hg

Changes in Cd concentrations were very slight under the various types of test conditions. The concentrations showed lower values with agitation, and were very near the concentrations of the original seawater.

Cr and Cu, although moderately released (6.5 to 10.9 factor), demonstrated very little variation with change in redox condition. Cr does not precipitate as sulfide, and under a strong reducing environment, the predominant form is the complex cation, $CrOH^{+2}$. Cu, under reducing conditions, is generally less soluble, especially if reduced sulfur species are present.

Hg concentrations varied slightly under the various environmental conditions. The concentration was higher in an oxidizing state than under slightly reducing conditions. Values from Type C experiments were high, indicating some probability of contamination. Compounds formed in the oxidizing state are probably the halide species--namely, $HgCl_4^{-2}$, $HgCl_2$, and $HgCl_3^{-}$--while under reducing conditions, bisulfide becomes the important controlling species.

The three metals showing the most significant change in concentration with change in redox condition are Fe, Mn, and Ni. Their transport phenomena behaved similarly, and the order of metal release followed:

reducing > slightly oxidizing > oxidizing

Ferrous constituents are generally more soluble than ferric constituents. The ratio of measured concentration to the original seawater background concentration was 165 for quiescent reducing conditions and 52 for agitated reducing conditions. The presence of Fe may be due to the high-

Table 12.18

Comparative Metal Release Factor

Individual element in seawater background = 1

Column Test Type	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
A	1.0	7.4	7.5	29.4	1.5	13.7	38.7	3.4	7.9
B	1.0	8.8	8.4	165.4	2.0	16.2	88.6	4.8	11.5
C	1.0	8.3	9.7	27.6	4.4	14.6	52.6	12.4	14.6
D	0.7	8.0	10.6	52.4	1.6	14.9	54.0	8.9	17.1
E	0.7	6.5	10.9	15.9	2.1	10.4	48.3	6.5	17.5
Ranges of seawater background, ppb	0.03-0.24	0.05-0.8	0.1-0.8	0.4-3.0	0.03-0.15	0.4-3.0	0.02-0.75	0.03-0.12	0.2-0.5

A = untreated seawater, quiescent

B = nitrogen prebubbled, quiescent

C = oxygen prebubbled, quiescent

D = continued bubbling with nitrogen

E = continued bubbling with air

er solubility of the Fe(II) species. Under oxidizing conditions, less soluble ferric oxides and hydroxides are formed, as shown by the lower release factor varying from 15.9 to 27.6 times over the seawater background.

Differences in release factors for Mn were very small. Under reducing conditions, the slightly higher release factor may be due to the appearance of appreciable amounts of the soluble Mn(II) compounds, which upon oxidation convert into the less soluble Mn(IV) compounds. However, the small difference testifies to the fact that Mn(II) is oxidized very slowly in an oxygenated seawater environment.

The release of Ni was relatively higher than that of Mn, and was higher than that obtained for Fe, except for a single case under quiescent reducing conditions. The nickel ion is strongly absorbed by the hydrated oxides of Fe and Mn. Under reducing conditions, the sulfide generally solubilizes. Ni is not subject to the direct control of sulfide, as it does not form the very insoluble sulfide in seawater. It can, however, be co-precipitated in a sulfide-rich environment with other metal sulfides.

The release of Pb and Zn under quiescent conditions showed higher values under oxidizing than under reducing conditions, with release factors ranging from 3.4 to 17.5. Under agitation, Pb demonstrated a reverse trend, while Zn released to a higher degree, with concentrations for both oxidizing and reducing conditions having similar values. Zn is very vulnerable to contamination, which could be one possible cause for the high readings. Experiments by Krauskopf (1956) showed that Zn and Pb, as well as Cu, absorb strongly to absorbents such as ferric oxide, MnO_2, clays, etc. These metals can also be readily precipitated as sulfides.

Table 12.19 shows the concentration of trace metals in each column test type compared to the range of concentrations found in the interstitial waters of the sediments. In most cases, the metal concentration determined from the column test was within the indicated range for interstitial waters, except for Fe and Zn, which showed lower concentrations, and Pb, which was slightly higher in 3 of the 5 column test types. As a whole, the release of metals other than Fe showed surprisingly low values under all conditions --despite high concentrations in the sediment phase and the large surface areas resulting from the fine particle sizes.

Nutrients. The raw data obtained from the column test samples for the nutrients were very irregular, precluding the

Table 12.19

Comparative Metal Concentration

Column Test Type	Ag	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
A	0.022	0.150	0.37	0.75	79.3	0.045	11.0	0.77	0.270	1.58
B	0.022	0.150	0.44	0.84	446.0	0.060	13.0	1.77	0.385	2.30
C	0.008	0.150	0.42	0.97	74.8	0.130	11.6	1.05	0.990	2.92
D	0.010	0.115	0.40	1.06	141.0	0.048	12.0	1.08	0.710	3.44
E	0.008	0.115	0.33	1.09	43.0	0.063	8.3	0.97	0.520	3.50
Ranges of Interstitial Waters, ppb	----	0.1-0.5	0.4-0.9	0.4-1.3	120-2000	----	6.0-100	0.6 2.5	0.3-0.45	10.0-24

All values in ppb

observation of a characteristic release and/or uptake pattern for each nutrient, sediment type, or test type. Some sort of generalization may be speculated insofar as the results indicate a varying degree of release of nutrients to the solution.

The addition of the water-sediment mixture to the water column causes the release of nutrients. The first 30 minutes showed a sudden release, followed by a slight decrease in nutrient concentration. Upon reaching an equilibrium state, the mixture stabilized or varied to only a slight degree up to the end of the experiment (72 hrs). Table 12.20 shows the group pattern for the individual nutrient. Tests under reducing conditions (Types B and D) generally exhibit a higher concentration level, with the agitated test (Type D) having a higher value. Slightly oxidizing conditions (Types A and C) assume a middle level, with Type E (oxidizing) generally releasing at a very low concentration level. In most of the tests, a sag in the concentration occurred between 2 and 8 hours.

Table 12.20. General Characteristics of Nutrient Release

Nutrient	Initial Concentration, ppm	Peak Release, ppm	After 8 hrs.
NH_3-N	0.04	0.15-0.36	steady or slightly up
Org-N	0.15	0.40-0.86	slightly up
PO_4^{-3}	0.025	0.30-0.88	steady or slightly down
SiO_2	1.5	10.5-22.8	slight to medium rise

The release of ammonia and organic nitrogen leveled off to a constant value or to a slight upward trend by the end of the experiment, after initial release and readsorption. The nitrogen release was greater for anaerobic environments. The amount and form of nitrogen in solution phase is, to a large extent, controlled by the D.O. content. Under oxidizing conditions, the organic nitrogen as well as ammonium ions are oxidized to nitrite and subsequently to nitrate ions. Under anaerobic conditions, the Kjeldahl (soluble) nitrogen increased in concentration.

As shown (Tables 12.6-12.15) phosphate was released in large quantities under reducing conditions. The initial release of dissolved phosphate originates from the interstitial waters as well as from the sediment whose top layer contains a high concentration of phosphate. The greatest release of phosphate occurred in oxygen-deficient waters. The release or precipitation of phosphate is associated and dependent upon (to a great extent) the form of iron.

Upon contact with the dissolved oxygen, the ferrous ion oxidizes to ferric ions which subsequently react with phosphate to form insoluble ferric phosphate according to the equation;

$$Fe^{+3} + PO_4^{-3} \longrightarrow FePO_4\ (s)$$

Under reducing conditions, ferrous iron is released and, depending on the presence of sulfides, the Fe^{+2} ion may form the insoluble ferrous sulfide and release PO_4^{-3} or form ferrous phosphate which has a low solubility. The following equations show the reactions:

$$FePO_4(s) + e \longrightarrow Fe^{+2} + PO_4^{-3} \quad \text{(reducing condition)}$$

$$Fe^{+2} + S^{-2} \longrightarrow FeS(s)$$

$$3Fe^{+2} + 2PO_4^{-3} \longrightarrow Fe_3(PO_4)_2(s)$$

The dissolved silica in the interstitial waters is generally enriched and much more concentrated than that in the overlying water, as shown by the instantaneous upsurge in concentration upon resuspension of the sediments. Under aerobic conditions, silica behaves like the trace elements by co-precipitating on the hydrated oxides of Fe and Mn (Burton and Liss, 1973). Under anaerobic conditions, the precipitate redissolves, releasing the Si into solution.

Test Results Relative to Standards. The results of the column test simulating dredging conditions show with certainty that certain trace metals and nutrients are released. However, comparison of the numerical values of the test data with those of the different governmental standards as tabulated Table 12.21 show that most of the magnitudes are insignificant. The trace metal contents meet the Ocean Discharge Standards of California (CSWRCB, 1972) and the more recent guidelines suggested by the National Academy of Science and the United States Environmental Protection Agency (1975).

Aside from turbidity, the depletion of oxygen can also pose serious problems for organisms in both fresh and marine

waters. The magnitude and duration of the short-term effects depend very much on the characteristics of the sediment and the existing water quality of the receiving waters. However, the short-term effects of metal release seem to be quite insignificant.

The only uncertainty about the water quality effects of open water disposal is the availability of trace contaminants to organisms, especially to filter-feeding organisms and certain species of algae. This must be mitigated through the direct treatment of dredged spoil to eliminate excessive quantities of suspended particulates in the water column.

Treatment Studies. Complete chemical characterization of Station C8 sediments is found in Table 12.1. It is clear from the data that Station C8 sediment is the most contaminated. Since Station C8 sediment was used throughout the experiment, all data resulting from this study should be viewed as the upper concentration limits for each contaminant. If there is no significant adverse water impact resulting from the study of contaminated sediment, then little impact should result from the disposal of less contaminated sediment.

Tables 12.21 - 12.25 summarize the experimental results of water quality parameters such as turbidity, suspended solids, dissolved oxygen, $\Sigma S^{=}$, and trace metals for different types of treatment. Complete information for the background column study without polymer treatment, as well as the allowable ocean water discharge standards set by the California State Water Resources Control Board (CSWRCB), are provided for comparison. These tables are self-explanatory. The data are also shown in Figures 12.5-12.14 (pp. 12.49-.58).

It is obvious that substantial improvement in water quality can result from the coagulation of the dredge spoil prior to its disposal into the receiving water, over the disposal of the dredge spoil without the addition of flocculant. However, treatment of effluent from the dike area shows slightly better results than the direct treatment of dredge spoils.

In the direct treatment of sediment-seawater mixture, concentrations of trace metals are well below (one order of magnitude) the ocean discharge requirements. If a settling time of 1 to 2 hours is provided, the concentration of suspended solids and turbidity can meet the required standards without any problem.

Chlorinated hydrocarbons were not listed, as none of

these substances can be detected in soluble phase. The items of chlorinated hydrocarbons investigated were PCB's (Arochlor 1242, 1254, 1260), Lindane, BHC, Heptachlor, Aldrin, Heptachlor Epoxide, Methoxychlor, Chlordane, Toxaphene, Dieldrin, DDE, DDD, DDT, and Endrin. The analytical sensitivity of the laboratory can detect substances on an order of magnitude below the CSWRCB requirement of total identifiable chlorinated hydrocarbon concentration of 2 ppb for 50% of the time. Phenolic compounds and cyanide were not detected in the water column. Also, there was no detectable sulfide present.

A comparison of the water quality resulting from the treatment of returned effluents from a diked disposal area and the direct treatment of sediment-seawater mixture can be summarized as follows:

(1) About 20% improvement in water quality was observed when selected coagulants were used to treat the returned effluent from a diked disposal area, over the direct treatment of the sediment-seawater mixture.

(2) The direct treatment of dredged sediment can save up to one-third of the polymer needed for coagulation.

(3) No significant difference in water quality resulted from the use of either selected coagulant, cationic polymer CAT-FLOC T or anionic polymer WT-3000.

(4) Total sulfide and chlorinated hydrocarbons are below the detection limit in the water column in both types of treatment.

CONCLUSIONS.

Column Studies.

(1) Most of the trace metals and nutrients show varying degrees of release. Most metal species, with the exception of Fe and Mn, show increases as the redox changes from oxidizing to reducing.

(2) Fe, Mn, and Ni showed the widest fluctuation in soluble metal content; the degree of increase is dependent on the existing redox environment.

(3) Cr, Cu, Pb, and Zn exhibited moderate release (<1.5 times seawater concentration).

(4) Ag, Cd, and Hg showed very little change under all test conditions.

(5) The concentration of Cr remained steady under both oxidizing and reducing conditions.

(6) Most trace metals and nutrients were more soluble under reducing conditions than under oxidizing conditions, except for Cu and Hg.

(7) The concentration of nutrients after the initial release remains more or less constant.

(8) The initial turbulent mixing of water and sediment releases the metal ions from the interstitial waters and the sediments.

(9) The major factors involved in the concentration of metal by seawater are adsorption to organic matter or hydrated oxides of Fe and Mn, precipitation and co-precipitation, metal complex formation, and biological processes.

(10) The D.O. content and redox condition, to a large extent, control the amount and species of soluble metal ions and nutrients.

(11) The D.O. in most cases was depleted and could be detrimental to most forms of marine life.

(12) Aside from the difficulty posed by ppb-range analytical work, contamination and adsorption to the container walls can also present serious problems in analysis.

(13) Under no test conditions can the soluble metal concentration of all the metals meet the values specified by the EPA Standard Elutriate Test (1975).

(14) In every case, the concentration of soluble metals can meet the Ocean Discharge Standards of California (CSWRCB, 1972) and the proposed EPA criteria for marine water quality (1975).

The relative release of soluble trace metals and nutrients can be divided into three broad categories, based on the data obtained:

(1) Those which were significantly increased in the elutriate ($\geq$ 5 times): lead, manganese, nickel, organic N.

(2) Those which were moderately increased in the elutriate (1.5-5 times): cadmium, copper, iron, silver.

(3) Those which met the EPA criteria ($\leq$ 1.5 times): chromium, silver, zinc, PO_4-P.

Treatment Studies. It is concluded from the results obtained in this study that direct treatment of seawater-sediment mixture with flocculants followed by underwater discharge of dredge spoil from hydraulic dredging pipes to the water column will not cause any detectable level of water quality deterioration. Given one or two hours' retention time in a confined disposal area, the water quality parameters from the proposed dredging operation should fall within the ocean water discharge requirements (CSWRCB, 1972).

The following recommendations are made in accordance with the results obtained:

1) The direct treatment of seawater-sediment mixture should be adopted to reduce the quantity of polymer used, as well as to eliminate the mechanical agitation needed in the case of treatment of returned effluent from the diked disposal area.

2) A special hydraulic dredger should be designed to allow the addition of selective flocculants immediately followed by the injection of air. The application points of air and flocculants should be placed before the suction pump to allow maximum mixing, so that the particulates from the dredged sediment can be flocculated along the transport pipeline prior to discharge.

3) The discharge pipeline should be placed immediately above the bottom sediment to facilitate the sedimentation of flocculated particles. In the case of submerged disposal, the high and low tide periods should be avoided, to allow sufficient settling of suspended solids behind the confined dike area.

Giving attention to the design of dredging equipment and construction of a confined dike to allow sufficient settling time, the proposed dredging operation of the LNG route and subsequent dike disposal of dredged sediment will not cause any significant problems in water quality in the receiving water.

IMPACTS

The impacts of dredging are considered to be short term, and are of two general sorts: 1) those related to the physical effects of sediments distributed through the water column and 2) those associated with chemically toxic or biostimulatory effects.

Physical effects include: 1) The destruction of the existing benthic habitat (discussed in Chapter 6), 2) siltation and smothering of benthic biota adjacent to the dredging activity; 3) clogging of respiratory surfaces of sessile, attached organisms and of fish in the plume area; 4) reduction of light transmittance affecting photosynthesis of phytoplankton and algae due to turbidity, and 5) anoxia in organisms due to the high oxygen demand of chemicals and organics released from bottom sediment reducing environment.

The toxic effects of release of chemicals are discussed in the present chapter and more extensively in Marine Studies of San Pedro Bay, California, Part 11. In most cases, the toxic materials shown in bulk analyses do not enter the water column or the food web except at ppb levels. In other cases, such as mercury, food chain amplification is extreme (Chen and Eichenberger, 1976: Reish and King, 1976). At some areas of high concentrations in Los Angeles harbor, no apparent effects have been identified in fish or in consumers.

Biostimulation, or increased reproduction potential, occurred at certain dilutions and not at others (Emerson, 1974; 1976).

Dredging in Los Angeles Harbor should represent a net improvement in the long term environmental quality. In the shallow channels with fine, silty bottoms, resuspension of pollutants and oxygen-demanding substances occurs under strong wind and wave conditions, when ships maneuver, and when fall cooling causes waters to turn over. Release of soluble metals occurs, as does oxygen depletion. Removal of large amounts of fine sediments and pollutants and deepending of channels should reduce these effects.

Dredging must be done by techniques which limit the area of disturbance and the trubidity plume as much as is possible and feasible. Clam shell dredges cause the greatest loss of spoil and high turbidity at the site. Limiting the area of disturbance permits rapid recolonization of biota from nearby populations, that are outside the immediate impact zone of siltation and turbidity. In the harbor area, tidal flushing helps to repopulate disturbed areas by transporting in plankton larvae and juveniles.

Because of the extensive controversy, discussion, and research on the impacts of dredge disposal (Krenkel, Harrison, and Burdick, 1976), the EPA has revised regulations for dredge spoil a number of times.

The following section on regulations is excerpted in part from Chen and Wang (1976) and updated by Eichenberger (pers. comm.). It should be emphasized that open ocean dumping is controlled by different regulations than ocean waste disposal but comparisons made are of value in assessing policy. Also, in confined area disposal, run-off or percolation is regarded as a waste water or water quality problem subject to other standards and regulation.

CRITERIA AND GUIDELINES FOR EVALUATING THE DISCHARGE OF DREDGED MATERIAL IN NAVIGATABLE WATERS

GUIDELINES FOR FEDERAL PERMITS

Guidelines published by the Environmental Protection Agency, in conjunction with the U.S. Army Corps of Engineers, are utilized by Corps District Engineers in the review of permit applications for the discharge of dredged or fill material in navigable waters (Corps of Engineers, 1975). These guidelines are applicable to any project or activity involving a discharge of dredged or fill material (EPA, 1975). Navigable waters are defined in Section 404 of the Federal Water Pollution Control Act Amendments of 1972, Public Law 92-500, to mean "the waters of the United States, including the territorial seas" (EPA, 1975).

A brief history and analysis of national and regional EPA guidelines is presented to illustrate some of the problems and uncertainties confronting proposed dredging operations.

History and Analysis

May, 1971. The early EPA "Criteria for Determining Acceptability of Dredged Spoil Disposal to the Nation's Waters" were based entirely upon gross concentrations (EPA, 1971). These criteria were developed as guidelines for the evaluation of proposals and applications for permits to dredge sediments from fresh and marine waters. When one or more of the following pollution parameters exceeded the numerical limits expressed below, the sediment would be considered polluted in all cases and, therefore, would be unacceptable for open water disposal.

Chemical Constituent	Concentration, %, dry weight basis
Volatile solids*	6.0
Chemical oxygen demand (COD)	5.0
Total Kjeldahl nitrogen	0.10
Oil and grease	0.15
Mercury	0.0001
Lead	0.005
Zinc	0.005

* TVS % (dry) = 1.32 + 0.98 (COD%)

The term "open waters" was not specifically defined and is subject to interpretation; however, it is generally accepted that it applied to:

(1) all open ocean areas, bays, estuaries, lakes, and rivers

(2) all landfill projects in which the dredge spoil return waters are permitted to drain directly in such areas (Macfarlane, 1974).

May, 1973. Pursuant to the Marine Protection Research and Sanctuaries Act of 1972, Pub. L 92-532, the following "Standard Elutriate Test" was developed by the EPA in conjunction with the Corps of Engineers to determine the pollution potential of dredged materials prior to ocean disposal (EPA, 1973).

> Dredged material will be considered unpolluted if it produces a standard elutriate in which the concentration of no major constituent is more than 1.5 times the concentration of the same constituent in the water from the proposed disposal site used for the testing. The "standard elutriate" is the supernatant resulting from the vigorous 30-minute shaking of 1 part bottom sediment with 4 parts water from the proposed disposal site followed by 1 hour of letting the mixture settle and appropriate filtration or centrifugation. "Major constituents" are those water quality parameters deemed critical for the proposed dredging and disposal sites taking into account known point or area source discharges in the area, and the possible presence in their waste of the materials.

These criteria apply to "waters of the territorial sea, the contiguous zone, and the oceans" (EPA, 1973), and have been used to determine whether or not a particular sediment may be discharged in open waters or must be disposed of in diked areas or on land (Lee and Plumb, 1974).

October, 1973. The Region IX Office of the EPA, in consideration of the need for criteria applicable to the discharge of dredge spoil into navigable and ocean waters and based upon data representative of local environmental conditions, developed Regional Interim Dredge Spoil Disposal Criteria (DSDC). The Regional Office began application of the DSDC for review of dredge spoil disposal projects in October of 1973 (EPA, Region IX, 1973).

The resulting criteria represent the interpretation and implementation of the 1973 national guidelines for dredging projects in California by the Regional EPA office. The DSDC specified the "Standard Elutriate Test" plus the following additional analyses and numerical limits:

(1) Elutriate analysis. The following tests were required on the elutriate and water from the disposal site for all projects:
   (a) Immediate oxygen demand (prior to settling, on elutriate only)
   (b) Biochemical oxygen demand (5-day, 20°C)
   (c) Suspended solids
   (d) Organohalogens

   On disposal proposed for inland navigable waters, the following tests were required for projects greater than 50,000 cu yds:

   (a) Phosphorus (total)
   (b) Total Kjeldahl nitrogen
   (c) Nitrate

(2) Bottom sediment analysis. The following bottom sediment analyses (dry weight basis) were required for all projects:

Parameter	Limit (ppm)
Mercury	1
Cadmium	2
Lead	50
Zinc	130
Oil and grease	1500

October, 1974. The DSDC of October 1973 were revised in consideration of (1) guidance from Headquarters on national policy for discharge of dredge spoil into navigable waters, (2) review comments on the DSDC submitted by local, State, and Federal agencies and industries, and (3) additional information. Regional Interim Dredge Spoil Disposal Criteria were revised, based on these inputs (DSDC-R1; EPA, Region IX, 1974).

DSDC-R1 did not include the "Standard Elutriate Test" and established new limits for bottom sediment concentrations for shallow marine and estuarine waters. Development of the DSDC-R1 for toxic substances was limited to mercury, cadmium, lead, zinc, and oil and grease. The DSDC-R1 could be amended or revised to reflect new information or to include additional toxic pollutants where the findings of investigations or research so warrant. Development of numerical criteria

applicable to organic matter, nutrients, and suspended matter contained in dredge spoil is not anticipated at this time.

DSDC-Rl requirements are as follows:

Marine (Shallow) and Estuarine Water

Pollutant	Maximum Spoil Concentration, ppm (dry weight basis)
Mercury	1.5
Cadmium	3.0
Lead	180
Zinc	300
Oil and grease	4000

In DSDC-Rl, Region IX of the EPA proposed restrictions for the discharge of fill material as follows:

(1) No permit shall be issued for the discharge of fill material without evaluation of (a) the need for the preparation of an environmental impact statement, and (b) the probable environmental impact of the fill discharge, of the activities on the fill site, and of further development on the fill site.

(2) No permit shall be issued for the discharge of fill material when the Regional Administrator determines that the material contains unacceptable quantities, concentrations, or forms of heavy metals, nutrients, pesticides, polychlorinated biphenyls, petroleum and non-petroleum oil and grease, oxygen-demanding substances, or materials designated as toxic pollutants, in accord with Section 307 of the FWPC Act, unless such material is effectively confined so as to prevent leaching, discharge, or erosion of the material outside of the confinement.

It is concluded from the foregoing statements that fill material may be confined in a diked area provided the effluent outflow meets applicable water quality standards.

May, 1975. On May 6, 1975, the EPA issued proposed guidelines to be used in controlling the discharge of dredged or fill material into navigable waters (EPA, 1975, "Navigable Waters--Discharge of Dredged or Fill Material"). Dredged material and fill material are defined as follows:

Dredged material--Any material in excess of one cubic meter when used in a single or incidental operation, excavated or dredged from navigable waters, including without limitation, runoff or overflow which occurs during a dredging operation or from a contained land or water disposal area.

Fill material--Any material discharged into navigable waters for a purpose other than disposal, including without limitation, the creation of fast land, or the production of intended elevation of land beneath the water.

Three interim test procedures were stipulated in the proposed guidelines: (1) elutriate test, (2) sediment analysis, and (3) total suspended solids. A brief description of the requirements follows.

Elutriate test. The elutriate test was initially specified by the EPA in May 1973. The following changes were incorporated into the proposed guidelines of May 1975.

(1) The test is required for both dredged and fill material.

(2) In cases where confined disposal is proposed, the elutriate test is used to determine if return flow will require restricted discharge conditions. The discharge site will be that area receiving return flows from the confined disposal area.

(3) The standard elutriate is prepared with water from the dredging site instead of using water from the proposed disposal site as previously required (EPA, 1973).

(4) A dilution factor of 10 is permitted to determine compliance with the 1.5 concentration requirement, based on the proposed disposal site.

(5) A final 0.45 μm filtration is required.

(6) Major constituents are those parameters deemed critical by the District Engineer and the Regional Administrator.

Sediment analysis. Extraction of total concentrations of parameters from a weighed portion of dredged or fill material will be accomplished by concentrated strong acid action for

inorganic parameters and solvent extraction for organic parameters. The resultant extracts will be individually analyzed by standard EPA procedures for major constituents.

Suspended solids. In the event that suspended solids (mg/l) are identified as a major constituent, one part of the 1:4 sediment-seawater slurry shall be withdrawn immediately upon completion of the 30-minute shaking period and dispersed within 10 parts (v/v) of water from the proposed discharge site, allowed to settle for 1 hour, and the uppermost layer analyzed gravimetrically for suspended solids. This result will then be compared to 1.5 times the ambient suspended solids concentration at the proposed discharge site.

Dredged or fill material will require restricted disposal conditions, if upon evaluation the results of the tests specified are deemed unacceptable by the Regional Administrator and the District Engineer.

Considerations for restricted disposal conditions include the following:

(1) Appropriate scientific literature, such as the National Water Quality Criteria developed by the Administrator, EPA, pursuant to Section 304(a) of the FWPC Act.

(2) Alternatives to open water disposal such as upland or confined disposal.

(3) Disposal sites where physical environmental characteristics are most amenable to the type of dispersion desired.

(4) Disposal seaward of the baseline.

(5) Covering contaminated dredged material with cleaner material.

(6) Conditions to minimize the effect of runoff from confined areas on the aquatic environment.

September, 1975. On September 5, 1975, the EPA issued interim final guidelines in order to provide immediate guidance in the implementation of the permit program under Section 404 of the Water Pollution Control Act Amendments of 1972 (EPA, 1975, "Navigable Waters--Discharge of Dredged or Fill Material"). Interim guidance to applicants concerning the applicability

of specific approaches or procedures will be furnished by the District Engineer.

These interim final guidelines are essentially a clarification of the May 6, 1975, proposed guidelines. Some of the changes made were based on comments received on various sections of the proposed guidelines of May 1975. The elutriate test, sediment analysis, and bioevaluation will be used, where appropriate, to determine the suitability of proposed disposal sites. One important change was the removal of 1.5 factor in the elutriate test in determining the potential effect of disposal of dredged materials. The EPA also acknowledges that no single test can be applied in all cases to evaluate the effects of proposed discharges of dredged or fill material. Technical evaluations will be required only when a case-by-case review indicates that the results will provide information necessary to reach a final decision. The results of an appropriate technical evaluation will serve as one of many factors involved in the decision-making process.

The national EPA guidelines of May 6 and September 5, 1975, indicate the elutriate test and sediment analysis may be required for both open water and confined disposal of dredged and fill material. The interpretation and implementation of the national guidelines by the Region IX office of the EPA is not available at the time of this publication.

There are strong reservations within the scientific community over the rationale and relevancy of the elutriate test and bulk sediment analysis as indicators of the pollution status of dredged or fill material. Critical comments by various investigators are presented in the following paragraphs.

Sediment analysis. Rationale: Suitability of the proposed disposal sites may be evaluated by the use of sediment analysis. Markedly different concentrations of critical constituents between the excavation and disposal sites may aid in making an environmental assessment of the proposed disposal operation (EPA, 1975).

Comments:

(1) Little is known about the relationship between the concentrations of various chemical constituents within sediments subject to dredging and disposal operations, and the consequent effects on water quality (Boyd, 1972).

(2) The presence of a constituent (toxin, biostimulant, etc.) in the sediment does not indicate or predict the nature and significance of adverse effects following disposal. This is because many chemical constituents found in sediments are

not bioavailable and do not react as pollutants (Keeley and Engler, 1974).

(3) A review of the literature on the release of chemical contaminants from dredge material and natural water sediments has shown that the bulk chemical composition is not a useful index of potential environmental quality problems for waters coming in contact with these sediments (Lee and Plumb, 1974).

(4) Gross sediment concentrations may not bear direct or linear relationship to biological potentials (Chen and Lu, 1974).

Obviously, most studies show that no direct correlation exists between the amounts of release/removal of metals and the gross metal content in the bulk sediment; therefore, the bulk chemical composition of the dredged sediment is not a proper index for indicating the potential polluting status of the sediments.

Elutriate test. Rationale: The elutriate test is used to predict the effect on water quality due to the release of contaminants from the sediment to the water column (EPA, 1975).

Comments:

(1) The elutriate test is a poor simulation of the environment affecting the availability of heavy metals in fresh and estuarine waters, or in marine waters, where the benthic community is a major concern (EPA, Region IX, 1974).

(2) The elutriate analysis points to a short-term water quality effect. However, such a procedure presents tremendous difficulties in practice. At present, the most serious problem in establishing such criteria is the extreme difficulty in evaluating the validity of data from seawater studies. The analysis of trace metals in seawater generally requires a highly sophisticated and elaborate laboratory setup with meticulous cleaning procedures. Even so, the variation of data from one laboratory to another is tremendous (Patterson, 1974). To create a new test such as the "Standard Elutriate Test" without thoroughly testing it prior to adoption certainly creates serious problems for the enforcement of regulations. The cost of setting up the necessary equipment to perform a meaningful study is generally beyond the reach of most laboratories. Additionally, the standard elutriate test as outlined in the EPA guidelines does not take into consideration the possible changes of environmental variables which may alter the availability of toxicants and nutrients for biota (Chen and Lu, 1974).

(3) It has been questioned whether water from the proposed project site (dredging site) should be mixed with the sediments or whether water from the proposed disposal site should be used. It can be argued that dredging site water should be used, since the test is designed to simulate the hydraulic dredging process. The ratio of sediment to water approximates the normal hydraulic pumping ratio; the vigorous shaking simulates the actual hydraulic dredging process; and during this process, net changes in dissolved concentrations may occur. On the other hand, this does not necessarily take into account changes that may occur at the disposal site due to environmental conditions different from those at the dredging site (Keeley and Engler, 1974).

It should be noted that national EPA guidelines have vacillated on this point. On May 16, 1973, the EPA specified water from the disposal site for preparation of the standard elutriate; on May 6, 1975, the requirement was changed to the use of water from the dredging site.

(4) The 1.5 factor has no toxicological or any other ecological basis. It is meant instead to serve as a guide to the amount of increase in dissolved chemical concentrations that should be allowed before taking into account dilution at the disposal site. However, if dissolved concentrations using project site water do not exceed the 1.5 factor, it is thought that dilution at the disposal site will reduce dissolved concentrations below any harmful levels (Keeley and Engler, 1974).

(5) It is possible that a disposal site might be selected, based on the 1.5 factor, which would allow a greater deterioration of water quality than would occur if this factor was not utilized. A key part in the 1.5 factor is the ambient concentration of selected chemical species in the disposal site water. It is possible that, by selecting a water with a high ambient background of a particular chemical species released in the elutriate test, disposal of dredge material would cause the waters in the disposal region to exceed the critical concentration for certain forms of aquatic life but not 1.5 times the ambient concentration. It is clear that the 1.5 factor should not be used as a rigid standard, but to detect potential problems. The proper interpretation of the amount of release that occurs requires consideration of the contaminant assimilative capacity in the disposal site water column relative to the critical concentration for this contaminant to selected organisms in the water column (Lee and Plumb, 1974).

(6) The arbitrary application of the 1.5 factor to determine whether a particular sediment is "polluted" is no

more technically sound than using bulk analysis. The proper interpretation of the elutriate test results requires consideration of the existing concentrations of each of the water quality parameters of concern in relationship to the amount of increase in concentrations that would occur in the disposal area. The sum of these two must be examined in light of the critical concentrations of the parameter for aquatic life of the receiving water (Lee and Plumb, 1974).

(7) It should be emphasized that the elutriate test is designed primarily to detect potential problems that could occur in the water columns of the respective areas during dredging and disposal. This test should also detect any potential problems occurring due to resuspension of the dredge material at the disposal site. It will not readily detect problems associated with dredging which are related to the physical effects of solids deposition on aquatic organisms, nor will it detect, to any significant extent, problems associated with dredging that may arise from the presence of chemical contaminants to benthic organisms. The environment that exists in the dredged sediments of the disposal site will probably be markedly different from the environment existing in the water columns at the dredging and disposal sites.

A review of the literature on the leaching of contaminants from dredge material and sediments shows that a wide variety of factors could affect the results of the elutriate test, including solid-liquid ratio, time of contact, pH, dissolved oxygen concentration, agitation, particle size, handling of solids, characteristics of water and sediments, and solid-liquid separation. It is apparent that a considerable amount of research is needed to establish the significance of these factors to the elutriate test results, for the many types of sediments that are likely to be dredged (Lee and Plumb, 1974).

The EPA acknowledges that many questions remain to be answered regarding means of evaluating the effects of dredged or fill material discharged in navigable waters (EPA, 1975).

Functionally, the elutriate test will measure the amount of trace contaminants and nutrients in the interstitial water and exchangeable phases of the sediments. However, any release factor should only be considered as an indicator as to whether the sediment involved will release chemical constituents from the solid phase into the solution phase. It may carry no ecological implication that any biota will be significantly affected or that water quality is impaired.

EPA Revisions

On June 28, 1976, the EPA published proposed revisions of the regulations and criteria with respect to the transportation of wastes for the purpose of ocean dumping (EPA, 1976). The proposed revisions affect both the procedures to be followed in reviewing applications for ocean dumping and the substantive criteria to be applied in evaluating these applications. A summary of the criteria to be used in evaluating disposal of dredged materials is presented.

"In order to predict the effect on water quality due to the release of contaminants from the sediment, an elutriate test may be used. The elutriate is the supernatant resulting from a vigorous 30-minute agitation of one part bottom sediment from the dredging site with four parts water (vol/vol.) collected from the dredging site followed by one hour settling time and appropriate contrifugation and a 0.45 μ filtration. Major constituents to be analyzed in the elutriate are those deemed critical by the District Engineer, after evaluating and considering any comments received from the Regional Administrator, and considering known sources of discharges in the area."

Consideration should also be given to concentrations of organohalogen compounds, mercury and mercury compounds, cadmium and cadmium compounds, oil of any kinds or in any form, arsenic, lead copper, zinc, organosilicon compounds, cyanides, fluorides, pesticides and their by-products.

"Particular attention should be given to the possible presence of major constituents that could cause an unacceptable oxygen demand or adverse chemical-biological interactive effects and known characteristics of the extraction and disposal sites. The dredged material will be considered as environmentally acceptable for ocean dumping if elutriate concentrations, after allowance is made for dilution... and consideration of the volume and rate of the proposed dumping, do not exceed the limiting permissible concentration."

"Initial Mixing (Dilution). a) Initial mixing is defined to be that dispersion or diffusion of a waste which occurs within four hours after dumping. The limiting permissible concentration shall not be exceeded at any point in the marine environment after initial mixing."

Limitations on Times and Rates of Disposal.

The total volume of material disposed of at any site shall not cause the concentration of the total materials or any constituents to exceed limits specified in the site designation.

Limiting Permissible Concentration

"With respect to dredged material, that concentration of a major constituent in the elutraite which, after allowance for initial mixing ... does not exceed applicable water quality criteria."

"If .. elutriate concentrations are found to exceed limiting permissible concentrations, the District Engineer may, after considering comment from the Regional Administrator, specify bioassays when such procedures will be of value in establishing dumping conditions or in determining if the dredged material if environmentally acceptable for ocean dumping."

In addition, if organohalogens, mercury, cadmium, and oil "... are present as other than trace contaminants the District Engineer will require the applicant to use such procedures to demonstrate that these constituents are 1) present in the wastes only as chemical compounds or forms (e.g., inert insoluble solid materials), non-toxic to marine life and non-bioaccumulative in the marine environment, or 2) present in the material only as chemical compounds or forms which, within four hours after disposal, will be rendered non-toxic to marine life and non-bioaccumulative in the marine environment by chemical or biological degradation in the sea; provided they will not make edible marine organisms unpalatable; or will not endanger human health or that of domestic animals, fish, shellfish, and wildlife. The procedure followed in the performance of any such bioassay will incorporate exposure times and concentrations determined from a knowledge of the proposed dumping rate and volume and of the hydrodynamics of the intended dumping area."

The interpretation of the proposed criteria can only lead to further confusion in the dredging industry. The definition of trace contaminant is essential in order to apply the proposed criteria. The EPA states that it is scientifically impossible to define trace contamination in numerical terms. Hopefully, the final regulations will clarify, or eliminate, this ambiguity.

It is concluded, based on the foregoing comments, that the elutriate test and sediment analysis are not adequate for determining the potential water quality impact resulting from the disposal of dredged or fill materials. Sediment analyses and elutriate tests for Los Angeles Harbor sediments are presented for comparison with the current guidelines.

This study was conducted under the assumption that the proposed dredging project will utilize either one of two methods of disposal: (1) confined disposal in a diked area, or (2) open water disposal. In the case of confined disposal, any degradation of water quality would be that caused by the effluent return from the diked area. Since this represents a source of discharge into ocean waters, the effluent quality requirements established by the California State Water Resources Control Board (CSWRCB) should be the applicable criteria in the absence of other relevant regulations. The requirements are given in Table 11 (CSWRCB, 1972). The same rationale for applicable criteria for open water disposal is applied.

Since each discharge of dredged or fill material into a navigable water is, in effect, the discharge of a pollutant into the water, a State water quality certification is required under Section 401 of the FWPC Act of 1972. Thus, any state may cause the denial of a Section 404 permit if it chooses to deny a water quality certification. Where a state denies a permit, the Corps of Engineers will not issue a Section 404 permit. On the other hand, if a state issues a permit, the Corps would not deny its permit unless there are overriding environmental factors, as reflected in the EPA guidelines (EPA, 1975).

In California, dredging of marine or freshwater sediments and subsequent disposal of the spoils are subject to a variety of existing, proposed, or inferred criteria, standards, and policies. These have been formulated by the EPA (national and Region IX), the California Coastal Zone Commission, the Regional California Coastal Zone Commissions, the Bureau of Fisheries and Wildlife, the California State Water Resources Control Board, the California Regional Water Quality Control Boards, and the California Department of Fish and Game (Macfarlane, 1974).

Nine California Regional Water Quality Control Boards are responsible for maintaining water quality in the State's inland and coastal waters. Any project which might affect water quality must comply with discharge requirements set by the governing regional board following a formal public hearing. The regional boards have at times required several

additional tests or procedures not required by other agencies, including:

a) analysis of composite samples from entire cores
b) fish bioassays
c) limited monitoring procedures for approved dredging operations
d) chemical analysis of interstitial waters extracted from sediment samples.

The Bureau of Sport Fisheries and Wildlife has, in the past, specified that additional coring and analysis, beyond that required by the EPA and the California Regional Water Quality Control Boards, must be carried out for harbor dredging projects involving the disposal of polluted spoils. The California Department of Fish and Game also has an interest in the ecological impacts of spoils in areas where substantial habitat damage is possible. But the department has not specified any requirements for analyzing dredge spoils (Macfarlane, 1974).

Additional marine water quality criteria have been proposed in the past three years (EPA, 1973 and 1975). The applicability of these criteria for open water and confined disposal has not been established. The proposed criteria are given below:

Constituent	California ocean discharge requirements (1972)		EPA Proposed water quality criteria (1973)	EPA, NAS proposed water quality criteria (1975)	
	50% of time	50% of time		EPA	NAS
Arsenic	0.01	0.02	0.05	0.2	0.2
Cadmium	0.02	0.03	0.01	0.1	0.01
Chromium	0.005	0.01	0.1	0.1	0.05
Copper	0.2	0.3	0.05	--	--
Lead	0.1	0.2	0.05	0.05	0.05
Mercury	0.001	0.002	0.1	0.1	0.1
Nickel	0.1	0.2	0.1	0.1	1.0
Silver	0.02	0.04	0.005	5.0	5.0
Zinc	0.3	0.5	0.1	0.2	--

Table 12.1

COMPOSITION OF SEDIMENTS.

Parameter \ Velero Sample Stn. No.	021909 C8	021910 C9	021911 C10	021912 C11	021913 B7	021914 B6
MC (%)	56.72	33.54	44.32	44.21	31.39	40.48
DM (%)	43.28	66.46	55.68	55.79	68.61	59.52
TOC (%)	2.082	0.827	1.380	0.967	0.365	0.901
COD	125,170	50,870	69,450	78,700	40,770	67,740
IOD	1,560	190	379	606	190	685
TVS (%)	8.34	4.38	4.60	4.93	2.66	5.08
$S^=$	1,890	452	383	510	236	1,323
Oil & Grease	4,260	1,470	1,530	1,630	1,320	1,710
Organic N	953	395	503	452	545	423
Total N	981	426	528	473	573	443
Total P	2,330	1,310	1,300	1,350	1,830	1,700
As	17.0	7.11	9.79	6.15	6.43	1.20
Cd	6.56	2.73	4.46	3.10	2.24	3.15
Cr	170	114	160	194	63.9	116
Cu	235	82.7	137	144	46.0	183
Fe	27,680	28,060	38,330	38,550	34,500	37,490
Hg	2.83	1.57	1.40	1.37	0.60	1.64
Mn	315	343	316	344	387	399
Ni	148	73.9	67.4	73.2	57.5	31.5
Pb	87.5	81.2	164	172	47.9	140
Zn	516	240	324	367	135	399
pp'DDE	13.88×10^{-3}	5.3×10^{-3}	8.9×10^{-3}	8.0×10^{-3}	6.7×10^{-3}	7.5×10^{-3}
op'DDE	6.9×10^{-3}	2.1×10^{-3}	2.9×10^{-3}	2.6×10^{-3}	3.2×10^{-3}	2.7×10^{-3}
pp'DDD	18.05×10^{-3}	6.1×10^{-3}	9.2×10^{-3}	9.1×10^{-3}	8.6×10^{-3}	7.2×10^{-3}
op'DDD	8.22×10^{-3}	1.7×10^{-3}	3.4×10^{-3}	3.0×10^{-3}	3.1×10^{-3}	2.1×10^{-3}
pp'DDT	---	---	---	---	---	---
op'DDT	---	---	---	---	---	---
Total DDT	47.20×10^{-3}	15.2×10^{-3}	24.4×10^{-3}	22.7×10^{-3}	21.6×10^{-3}	19.5×10^{-3}
Arochlor 1242	5.200	2.20	3.40	3.10	3.30	2.99
Arochlor 1254	0.480	0.20	0.39	0.37	0.38	0.30
Arochlor 1260	0.048	0.02	0.039	0.036	0.037	0.03
Total PCB	5.728	2.42	3.829	3.506	3.717	3.32
Dieldrin	---	---	---	---	---	---

All units in ppm unless specified.

Parameter \ Velero Sample Stn. No.	021915 B5	021916 B4	021917 B3	021918 B2	021919 B1	021920 B11
MC (%)	28.30	28.33	45.45	42.17	27.49	46.06
DM (%)	71.70	71.67	54.55	57.83	72.51	53.94
TOC (%)	0.407	0.950	1.137	1.021	0.400	1.009
COD	28,330	29,690	48,140	34,360	15,250	68,920
IOD	445	290	481	368	438	590
TVS (%)	2.77	4.27	6.38	4.94	2.19	5.92
$S^=$	229	463	340	519	78.0	666
Oil & Grease	1,410	1,130	1,780	1,670	1,120	1,860
Organic N	195	200	411	242	270	311
Total N	218	220	424	258	285	320
Total P	1,120	1,220	1,580	1,230	1,300	1,390
As	1.83	2.72	8.60	1.02	1.59	6.72
Cd	2.24	2.77	2.79	2.54	1.98	2.71
Cr	65.7	72.1	101	67.7	36.4	78.1
Cu	45.6	58.3	76.0	49.1	43.1	61.6
Fe	26,300	39,360	43,410	42,590	22,730	41,330
Hg	0.80	0.49	0.36	0.26	0.11	0.38
Mn	339	489	457	446	350	386
Ni	27.6	58.2	77.5	72.8	33.1	67.4
Pb	92.0	72.1	104	76.2	38.4	98.6
Zn	133	147	178	140	61.0	156
pp'DDE	0.58×10^{-3}	1.26×10^{-3}	7.03×10^{-3}	3.9×10^{-3}	3.10×10^{-3}	5.7×10^{-3}
op'DDE	0.26×10^{-3}	0.37×10^{-3}	3.67×10^{-3}	2.7×10^{-3}	1.25×10^{-3}	1.9×10^{-3}
pp'DDD	0.70×10^{-3}	1.03×10^{-3}	5.81×10^{-3}	3.3×10^{-3}	3.82×10^{-3}	4.7×10^{-3}
op'DDD	0.26×10^{-3}	0.33×10^{-3}	1.83×10^{-3}	1.08×10^{-3}	1.07×10^{-3}	1.9×10^{-3}
pp'DDT	---	---	---	---	---	---
op'DDT	---	---	---	---	---	---
Total DDT	1.80×10^{-3}	2.99×10^{-3}	18.34×10^{-3}	10.98×10^{-3}	9.24×10^{-3}	14.2×10^{-3}
Arochlor 1242	0.46	0.48	1.60	1.40	1.3	1.60
Arochlor 1254	0.04	0.042	0.13	0.11	0.1	0.150
Arochlor 1260	0.004	0.004	0.013	0.011	0.01	0.015
Total PCB	0.504	0.526	1.743	1.521	1.41	1.765
Dieldrin	---	---	---	---	---	---

All units in ppm unless specified.

COMPOSITION OF SEDIMENTS, CONTINUED.

Table 12.1 (cont'd)

Parameter \ Velero Sample Stn. No.	021921 B10	021922 B9	021923 B8	021924 A12	021925 A11	021927 A6
MC (%)	35.52	42.21	29.98	29.86	29.28	41.47
DM (%)	64.48	57.79	70.02	70.14	70.72	58.53
TOC (%)	1.160	1.142	0.342	0.561	0.302	1.510
COD	35,910	43,280	17,230	26,100	19,860	83,200
IOD	479	1,131	611	664	623	1,698
TVS (%)	5.21	5.19	2.94	3.14	2.41	7.70
$S^=$	1,358	1,351	491	128	86.0	1,510
Oil & Grease	1,730	1,420	1,090	1,130	1,020	1,480
Organic N	304	388	280	313	283	412
Total N	323	397	297	325	297	435
Total P	1,560	1,220	1,120	1,270	1,150	1,530
As	3.82	4.31	1.01	1.78	0.53	3.41
Cd	2.05	3.10	2.14	1.87	2.20	1.76
Cr	92.0	73.6	48.8	62.3	58.3	42.2
Cu	53.4	48.1	36.6	38.6	49.9	215
Fe	44,370	38,760	31,420	25,730	27,820	12,310
Hg	0.46	0.43	0.16	0.42	0.25	4.17
Mn	456	440	420	394	422	331
Ni	86.3	58.9	47.6	48.8	55.5	45.7
Pb	111	85.3	56.1	46.7	72.2	66.8
Zn	177	146	97.6	126	128	281
pp'DDE	5.3×10^{-3}	5.9×10^{-3}	3.0×10^{-3}	5.6×10^{-3}	3.0×10^{-3}	7.03×10^{-3}
op'DDE	1.7×10^{-3}	2.3×10^{-3}	1.23×10^{-3}	1.4×10^{-3}	1.24×10^{-3}	3.67×10^{-3}
pp'DDD	4.2×10^{-3}	4.8×10^{-3}	3.7×10^{-3}	4.3×10^{-3}	3.8×10^{-3}	$5\ 6\times10^{-3}$
op'DDD	1.3×10^{-3}	2.2×10^{-3}	1.02×10^{-3}	1.6×10^{-3}	1.06×10^{-3}	1.9×10^{-3}
pp'DDT	---	---	---	---	---	---
op'DDT	---	---	---	---	---	---
Total DDT	12.5×10^{-3}	15.2×10^{-3}	8.95×10^{-3}	12.0×10^{-3}	9.10×10^{-3}	18.20×10^{-3}
Arochlor 1242	1.400	1.62	1.20	1.3	1.2	2.0
Arochlor 1254	0.130	0.16	0.12	0.1	0.13	0.20
Arochlor 1260	0.013	0.015	0.011	0.011	0.012	0.02
Total PCB	1.543	1.795	1.331	1.411	i.342	2.22
Dieldrin	---	---	---	---	---	---

All units in ppm unless specified.

Parameter \ Velero Sample Stn. No.	021928 A5	021929 A4	021930 A3	021931 A2	021932 A1	021933 A2
MC (%)	52.97	51.38	29.33	33.30	27.50	38.63
DM (%)	47.03	48.62	70.77	66.70	72.49	61.37
TOC (%)	1.523	1.465	0.384	1.032	0.629	0.977
COD	91,890	91,010	23,230	51,540	31,100	58,280
IOD	1,429	1,219	412.2	589.2	429.9	643.7
TVS (%)	7.38	7.33	2.74	4.89	3.42	4.81
$S^=$	1,320	1,215	188	513	160	788
Oil & Grease	1,450	1,840	1,070	1,340	1,140	1,480
Organic N	357	303	171	198	252	305
Total N	378	334	192	206	260	326
Total P	1,690	1,660	910	1,150	980	1,100
As	9.0	4.77	1.87	4.33	7.70	3.30
Cd	5.02	5.44	2.68	2.86	1.26	2.63
Cr	102	109	59.6	63.5	64.7	87.5
Cu	191	149	48.9	49.6	36.4	97.1
Fe	45,340	45,370	28,070	30,300	21,480	34,240
Hg	2.10	1.37	0.30	0.41	0.19	0.54
Mn	351	349	387	402	298	355
Ni	85.3	77.1	47.7	50.8	37.7	63.7
Pb	110	141	56.6	59.1	62.8	71.7
Zn	381	332	116	133	81.7	167
pp'DDE	5.7×10^{-3}	5.2×10^{-3}	1.7×10^{-3}	1.27×10^{-3}	4.2×10^{-3}	5.3×10^{-3}
op'DDE	1.5×10^{-3}	1.8×10^{-3}	0.28×10^{-3}	0.38×10^{-3}	2.8×10^{-3}	1.6×10^{-3}
pp'DDD	4.9×10^{-3}	4.1×10^{-3}	1.01×10^{-3}	1.02×10^{-3}	3.6×10^{-3}	4.8×10^{-3}
op'DDD	1.8×10^{-3}	1.0×10^{-3}	0.30×10^{-3}	0.34×10^{-3}	1.2×10^{-3}	1.7×10^{-3}
pp'DDT	---	---	---	---	---	---
op'DDT	---	---	---	---	---	---
Total DDT	13.9×10^{-3}	12.1×10^{-3}	3.28×10^{-3}	3.01×10^{-3}	11.8×10^{-3}	13.4×10^{-3}
Arochlor 1242	1.8	1.20	0.42	0.41	1.42	1.30
Arochlor 1254	0.18	0.13	0.04	0.04	0.14	0.12
Arochlor 1260	0.018	0.013	0.039	0.038	0.014	0.012
Total PCB	1.998	1.343	0.499	0.488	1.574	1.432
Dieldrin	---	---	---	---	---	---

All units in ppm unless specified.

Table 12.1 (cont'd)

COMPOSITION OF SEDIMENTS, CONTINUED.

Parameter \ Velero Sample Stn. No.	021934 A8	021935 A9	021936 A10	021937 C1	021939 C3	021940 C4
MC (%)	57.56	37.17	52.60	21.94	34.04	29.28
DM (%)	42.44	62.83	47.40	78.06	65.96	70.72
TOC (%)	1.613	1.575	1.744	0.673	1.065	0.538
COD	11,050	93,120	119,280	39,440	33,810	42,340
IOD	852.3	1,355	610	981	640.7	594.9
TVS (%)	9.41	7:01	8.94	2.24	3.92	2.71
$S^=$	4,216	1,162	2,003	311	243	241
Oil & Grease	2,130	1,810	2,050	1,150	1,280	1,320
Organic N	820	206	513	107	298	177
Total N	845	231	532	123	301	193
Total P	2,170	918	1,490	652	1,450	715
As	15.22	5.67	6.07	2.19	3.31	2.78
Cd	2.29	2.57	4.57	0.89	2.96	1.50
Cr	126	85.9	95.2	34.6	95.4	77.8
Cu	296	67.0	252	47.0	85.5	74.8
Fe	40,440	37,460	36,000	18,210	34,210	26,950
Hg	1.03	0.10	1.48	0.40	0.82	0.73
Mn	315	335	247	210	428	349
Ni	74.5	85.9	66.7	17.3	36.8	38.9
Pb	115	60.2	95.2	49.5	112	104
Zn	246	146	262	89.1	201	153
pp'DDE	11.9×10^{-3}	3.3×10^{-3}	6.6×10^{-3}	0.90×10^{-3}	4.7×10^{-3}	1.78×10^{-3}
op'DDE	6.3×10^{-3}	2.6×10^{-3}	3.1×10^{-3}	0.21×10^{-3}	1.3×10^{-3}	0.29×10^{-3}
pp'DDD	17.0×10^{-3}	3.6×10^{-3}	8.1×10^{-3}	1.0×10^{-3}	4.7×10^{-3}	1.03×10^{-3}
op'DDD	8.1×10^{-3}	1.2×10^{-3}	2.0×10^{-3}	0.15×10^{-3}	1.7×10^{-3}	0.35×10^{-3}
pp'DDT	---	---	---	---	---	---
op'DDT	---	---	---	---	---	---
Total DDT	43.2×10^{-3}	10.7×10^{-3}	19.8×10^{-3}	2.26×10^{-3}	12.4×10^{-3}	3.45×10^{-3}
Arochlor 1242	4.8	1.32	3.10	0.20	1.7	0.44
Arochlor 1254	0.42	0.13	0.31	0.02	0.175	0.04
Arochlor 1260	0.042	0.013	0.03	0.0019	0.018	0.0041
Total PCB	5.262	1.463	3.44	0.2219	1.893	0.4841
Dieldrin	---	---	---	---	---	---

All units in ppm unless specified.

Parameter \ Velero Sample Stn. No.	021941 C6	021942 C5	021943 C7	021944 D1	021945 D2	021946 D3
MC (%)	45.02	45.15	44.32	45.49	45.22	51.19
DM (%)	54.98	54.85	55.68	54.51	54.78	48.81
TOC (%)	0.947	1.235	1.339	1.423	2.239	1.213
COD	58,130	55,540	106,120	[illegible],120	128,520	71,420
IOD	813.9	848.5	1,480.3	851.8	947.6	1,037
TVS (%)	4.55	6.06	3.94	5.74	10.16	7.93
$S^=$	381	1,610	588	1,841	4,522	2,746
Oil & Grease	1,660	2,010	4,030	1,860	2,100	2,120
Organic N	449	508	402	411	511	559
Total N	568	523	425	434	541	586
Total P	1,227	1,411	1,241	1,109	1,299	1,489
As	6.13	3.87	2.79	4.95	1.70	2.21
Cd	2.68	4.64	3.39	2.38	2.26	4.35
Cr	161	114	161	63.6	38.7	104
Cu	123	139	258	55.6	56.8	87.0
Fe	38,070	35,640	38,360	41,180	19,380	44,900
Hg	0.714	0.465	0.424	0.204	0.147	0.248
Mn	398	329	383	393	262	341
Ni	82.2	76.0	50.8	79.5	42.6	78.3
Pb	145	219	258	119	375	413
Zn	246	275	381	159	255	342
pp'DDE	7.9×10^{-3}	8.6×10^{-3}	7.0×10^{-3}	7.2×10^{-3}	9.1×10^{-3}	11.2×10^{-3}
op'DDE	2.6×10^{-3}	2.7×10^{-3}	3.3×10^{-3}	3.4×10^{-3}	3.1×10^{-3}	4.1×10^{-3}
pp'DDD	9.0×10^{-3}	9.2×10^{-3}	5.2×10^{-3}	5.4×10^{-3}	9.8×10^{-3}	9.9×10^{-3}
op'DDD	2.8×10^{-3}	3.4×10^{-3}	1.9×10^{-3}	2.2×10^{-3}	3.8×10^{-3}	3.9×10^{-3}
pp'DDT	---	---	---	---	---	---
op'DDT	---	---	---	---	---	---
Total DDT	22.3×10^{-3}	23.9×10^{-3}	17.4×10^{-3}	18.2×10^{-3}	25.8×10^{-3}	29.1×10^{-3}
Arochlor 1242	2.90	3.6	2.0	2.2	3.6	3.8
Arochlor 1254	0.29	0.36	0.20	0.22	0.36	0.38
Arochlor 1260	0.03	0.035	0.021	0.022	0.036	0.038
Total PCB	3.22	3.995	2.221	2.442	3.996	4.218
Dieldrin	---	---	---	---	---	---

All units in ppm unless specified.

Table 12.1 (cont'd)

Velero Sample Stn. No. / Parameter	021947 D4	20928 D5	20929 D6	20930 D7	20931 D8	20932 D9
MC (%)	22.68	30.20	40.08	53.38	23.25	26.05
DM (%)	77.32	69.80	59.92	46.62	76.75	73.95
TOC (%)	1.296	0.861	1.302	1.480	0.185	0.304
COD	2,953	7,800	29,100	43,400	4,250	8,810
IOD	1,134	207	503	463	77	180
TVS (%)	6.19	2.22	5.66	8.18	1.46	2.24
$S^{=}$	1,645	68	1,710	1,580	45	71
Oil and Grease	3,970	655	1,080	910	562	732
Organic N	145	260	632	1,060	146	234
Total N	151	260	632	1,060	146	234
Total P	819	1,320	1,450	1,500	312	1,330
As	1.42	1.96	3.75	4.01	1.05	2.05
Cd	1.90	1.78	1.71	2.68	0.62	5.22
Cr	64.6	27.5	47.2	61.6	12.3	64.6
Cu	39.2	6.46	29.1	36.1	4.00	15.1
Fe	32,150	10,180	22,880	31,250	4,760	16,440
Hg	0.083	0.067	0.218	0.291	0.178	0.079
Mn	301	211	265	300	56.9	272
Ni	45.6	17.1	35.2	44.6	12.2	34.4
Pb	139	37.2	72.6	85.0	29.2	122
Zn	148	31.7	102	119	13.8	85.3
pp'DDE	1.60×10^{-3}	544×10^{-3}	904×10^{-3}	811×10^{-3}	38.3×10^{-3}	39.9×10^{-3}
op'DDE	0.25×10^{-3}	97.8×10^{-3}	157×10^{-3}	118×10^{-3}	10.1×10^{-3}	15.3×10^{-3}
pp'DDD	1.0×10^{-3}	333×10^{-3}	711×10^{-3}	623×10^{-3}	32.8×10^{-3}	43.1×10^{-3}
op'DDD	0.32×10^{-3}	71.3×10^{-3}	130×10^{-3}	98.3×10^{-3}	11.3×10^{-3}	18.7×10^{-3}
pp'DDT	---	30.4×10^{-3}	122×10^{-3}	60.9×10^{-3}	---	---
op'DDT	---	15.4×10^{-3}	51.3×10^{-3}	31.8×10^{-3}	---	---
Total DDT	3.17×10^{-3}	1092×10^{-3}	2076×10^{-3}	1743×10^{-3}	92.5×10^{-3}	117×10^{-3}
Arochlor 1242	0.33	0.4	---	---	---	---
Arochlor 1254	0.03	0.4	---	---	---	---
Arochlor 1260	0.003	0.04	---	---	---	---
Total PCB	0.363	0.84	---	---	---	---
Dieldrin	---	---	---	---	---	---

All units in ppm unless specified.

Table 12.6

COLUMN TEST SERIES
I

Time (hrs) Elapsed	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	D.O. mg/l	pH	$S^=$ mg/l
0	0.02	0.21	0.20	20	0.120	1.0	0.05	0.13	0.38	7.0	7.9	0.01
0.5	0.01	3.6	0.04	155	0.030	9.8	0.14	0.07	0.51	0.0	7.8	1.91
1	0.04	0.8	0.06	4.20	0.053	6.3	0.07	0.06	0.81	0.0	7.9	0.11
2	0.04	0.7	0.08	160	0.041	5.6	0.06	0.06	0.63	0.0	7.7	0.03
4	0.02	0.4	0.05	110	0.034	3.1	0.005	0.04	0.54	0.0	7.6	0.04
8	0.006	0.35	0.03	91	0.065	2.4	0.006	0.05	0.56	0.0	7.5	0.02
12	0.005	0.32	0.02	74	0.050	2.5	0.003	0.04	0.47	0.0	7.7	0.02
24	0.005	0.28	0.02	75	0.030	2.1	0.001	0.03	0.36	0.0	7.7	0.03
48	0.004	0.20	0.02	71	0.035	1.7	0.002	0.01	0.24	0.0	7.6	0.04
72	0.004	0.10	0.01	71	0.034	1.6	0.001	0.01	0.20	0.1	7.6	0.03
Original Sea water	0.08-0.24	0.05-0.8	0.1-0.8	0.4-3.0	0.03-0.15	0.4-3.0	0.02-0.75	0.03-0.12	0.02-0.5	6.8-8.0	7.8-8.0	0.00

All trace metals in ppb.

Sediment/seawater 1/20 by volume.

Water Quality of Soluble Phase in the Mixture of Seawater and Station A5 Sediment under Quiescent Settling Conditions (Type A)

Time (hrs) Elapsed	Total Phosphorus	Phosphate	Kjeldahl Nitrogen	NH_3-N	Organic Nitrogen	Silicate	Temp. °C
0	0.030	0.09	0.133	0.020	0.133	1.70	24.0
0.5	1.050	0.830	0.590	0.180	0.410	9.10	24.0
1	0.460	0.410	0.430	0.105	0.325	10.80	24.0
2	0.405	0.385	0.568	0.110	0.458	9.05	24.5
4	0.360	0.370	0.665	0.135	0.530	9.10	25.0
8	0.355	0.350	0.688	0.143	0.545	8.10	24.5
12	0.450	0.450	0.654	0.138	0.516	10.23	25.0
24	0.410	0.340	0.710	0.141	0.569	13.21	26.0
48	0.410	0.410	0.805	0.127	0.678	14.15	25.5
72	0.400	0.400	0.790	0.130	0.660	13.80	25.8

All units in mg/l except temperature.

Table 12.7

COLUMN TEST SERIES

II

Time (hrs) Elapsed	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	D.O. mg/l	pH	S= mg/l
0	0.30	0.41	3.15	6.3	0.051	0.07	4.35	1.85	5.15	0.35	7.8	0.03
0.5	0.14	0.80	2.0	9.6	0.005	0.04	4.90	1.10	6.35	0.0	8.0	4.02
1	0.09	0.90	0.3	25	0.007	0.80	4.40	0.80	5.70	0.0	7.35	4.65
2	0.08	0.95	0.05	8.0	0.035	0.70	4.8	0.45	5.40	0.0	7.35	2.80
4	0.03	0.93	0.02	9.1	0.025	0.50	4.7	0.43	5.35	0.0	7.20	3.50
8	0.01	0.68	0.02	17	0.030	0.65	4.8	0.46	4.30	0.0	7.40	4.90
12	0.002	0.35	0.01	8.3	0.030	0.55	3.0	0.45	3.50	0.0	7.35	4.80
24	0.002	0.40	0.25	8.5	0.025	0.60	2.7	0.44	2.95	0.0	7.41	4.60
48	0.001	0.35	0.01	7.5	0.024	0.70	4.3	0.45	0.5	0.0	7.40	4.70
72	0.001	0.35	0.01	7.8	0.020	0.60	4.5	0.43	0.4	0.0	7.40	4.60
Original Sea water	0.03-0.24	0.05-0.8	0.1-0.8	0.4-3.0	0.03-0.15	0.4-3.0	0.02-0.75	0.03-0.12	0.2-0.5	6.8-8.0	7.8-8.0	0.00

All trace metals in ppb.

Sediment/seawater 1/20 by volume.

<u>Water Quality of Soluble Phase in the Mixture of Deaerated Seawater and Station A5 Sediment under Quiescent Settling Conditions (Type B)</u>

Time (hrs) Elapsed	Total Phosphorus	Phosphate	Kjeldahl Nitrogen	NH_3-N	Organic Nitrogen	Silicate	Temp. °C
0	0.010	0.010	0.15	0.020	0.130	1.10	21.0
0.5	0.65	0.60	0.85	0.380	0.470	15.4	21.5
1	0.61	0.55	0.70	0.280	0.420	14.6	20.9
2	0.61	0.60	0.78	0.295	0.485	13.0	20.5
4	0.61	0.56	0.85	0.225	0.625	12.9	21.4
8	0.60	0.54	0.84	0.210	0.630	13.2	20.5
12	0.60	0.57	0.90	0.265	0.625	11.0	20.8
24	0.58	0.55	0.88	0.240	0.640	12.2	21.0
48	0.58	0.55	0.90	0.210	0.690	13.4	20.3
72	0.59	0.54	0.87	0.220	0.650	12.8	19.8

All units in mg/l except temperature.

Table 12.8

COLUMN TEST SERIES
III

Time (hrs) Elapsed	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	D.O. mg/l	pH	$S^=$ mg/l
0	0.5	0.30	3.20	4.0	0.14	0.11	2.5	4.0	8.5	7.2	8.0	0.08
0.5	0.45	0.30	1.30	23.0	0.02	2.20	3.1	1.1	8.4	0.0	7.5	0.110
1	0.26	0.20	1.00	110	0.135	1.80	0.9	0.3	11.0	0.0	7.6	0.070
2	0.30	0.15	1.25	125	0.01	0.85	1.0	3.0	6.3	0.1	7.7	0.080
4	0.15	0.10	1.05	95	0.105	0.80	0.9	0.5	10.0	0.0	7.9	0.060
8	0.12	0.75	1.30	105	0.110	0.85	0.5	0.85	3.0	0.0	7.7	0.060
12	0.03	0.45	1.30	106	0.102	0.95	0.5	1.30	0.9	0.0	7.8	0.070
24	0.05	0.50	0.40	85	0.110	0.81	0.4	0.80	4.0	0.0	7.8	0.100
48	0.09	0.30	0.50	125	0.030	0.45	0.3	0.40	5.1	0.0	7.9	0.101
72	0.08	0.40	0.40	12-	0.020	0.40	0.3	0.35	1.4	0.0	7.9	0.090
Original Sea water	0.03-0.24	0.05-0.8	0.1-0.8	0.4-3.0	0.03-0.15	0.4-3.0	0.02-0.75	0.03-0.12	0.2-0.5	6.8-8.0	7.8-8.0	0.00

All trace metals in ppb.

Sediment/seawater 1/20 by volume.

Water Quality of Soluble Phase in the Mixture of Compressed Air Aerated Seawater and Station A5 Sediment under Quiescent Settling Conditions (Type C)

Time (hrs) Elapsed	Total Phosphorus	Phosphate	Kjeldahl Nitrogen	NH_3-N	Organic Nitrogen	Silicate	Temp. °C
0	0.020	0.013	0.200	0.02	0.180	1.80	18.0
0.5	0.45	0.40	0.650	0.20	0.450	11.30	18.0
1	0.45	0.35	0.500	0.150	0.350	12.60	17.5
2	0.44	0.40	0.560	0.155	0.405	10.80	18.1
4	0.47	0.44	0.760	0.160	0.600	10.20	17.5
8	0.48	0.45	0.700	0.140	0.560	9.00	17.6
12	0.46	0.45	0.690	0.125	0.565	8.10	17.4
24	0.47	0.44	0.705	0.120	0.595	7.90	17.6
48	0.46	0.44	0.700	0.125	0.575	12.30	17.3
72	0.45	0.41	0.695	0.135	0.565	13.60	17.5

All units in mg/l except temperature.

Table 12.9
COLUMN TEST SERIES
IV

Time (hrs) Elapsed	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	D.O. mg/l	pH	$S^=$ mg/l
0	0.10	0.40	5.0	9.5	0.20	0.41	2.4	2.5	5.3	0.2	8.43	0.04
0.5	0.08	0.40	1.0	1520	0.04	1.5	3.1	2.9	5.8	0.1	8.45	0.05
1	0.06	0.38	0.9	175	0.02	1.4	1.2	3.3	5.7	0.0	8.53	0.05
2	0.11	0.41	1.40	167	0.20	1.1	1.4	3.4	5.9	0.0	8.46	0.06
4	0.05	0.43	1.3	150	0.18	1.5	0.8	3.1	5.8	0.0	8.63	0.07
8	0.14	0.48	1.2	170	0.04	1.0	0.7	1.6	6.1	0.0	8.77	0.08
12	0.10	0.50	1.4	41.0	0.06	1.1	1.05	1.5	6.0	0.0	8.90	0.05
24	0.11	0.46	1.5	25	0.05	1.1	1.1	1.7	6.0	0.0	8.90	0.04
48	0.10	0.45	1.6	24.0	0.07	1.3	0.8	1.6	6.1	0.0	8.75	0.04
72	0.09	0.46	1.3	38.0	0.06	1.4	1.6	1.7	6.0	0.0	8.71	0.05
Original Sea water	0.03-0.24	0.05-0.8	0.1-0.8	0.4-3.0	0.03-0.15	0.4-3.0	0.02-0.75	0.03-0.12	0.2-0.5	6.8-8.0	7.8-8.0	0.00

All trace metals in ppb.

Sediment/seawater 1/20 by volume.

Water Quality of Soluble Phase in the mixture of Deaerated Seawater and Station A5 Sediment under Agitated Settling Conditons (Type D)

Time (hrs) Elapsed	Total Phosphorus	Phosphate	Kjeldahl Nitrogen	NH_3-N	Organic Nitrogen	Silicate	Temp. °C
0	0.125	0.091	0.165	0.012	0.153	1.75	21.0
0.5	0.220	0.195	0.226	0.011	0.215	19.63	21.5
1	0.320	0.303	0.205	0.013	0.192	18.10	21.0
2	0.310	0.291	0.262	0.012	0.250	16.05	21.1
4	0.240	0.205	0.526	0.012	0.514	14.34	20.5
8	0.340	0.321	0.606	0.021	0.585	15.10	19.5
12	0.305	0.296	0.798	0.038	0.760	15.35	30.0
24	0.310	0.295	0.745	0.035	0.710	16.70	21.0
48	0.305	0.288	0.725	0.060	0.665	17.70	19.5
72	0.310	0.278	0.730	0.055	0.675	16.90	19.8

All units in mg/l except temperature.

Table 12.10

COLUMN TEST SERIES
V

Time (hrs) Elapsed	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	D.O. mg/l	pH	$S^=$ mg/l
0	0.010	0.50	0.14	9.8	0.04	0.4	0.003	0.30	0.30	6.7	7.75	0.002
0.5	0.003	1.05	0.08	10.0	0.07	1.9	0.07	0.02	2.10	0.0	7.84	0.00.
1	0.005	0.21	0.04	85.0	0.08	7.5	0.08	0.03	1.90	0.4	7.84	0.003
2	0.007	0.24	0.06	20.0	0.06	6.2	0.04	0.05	1.82	3.5	7.80	0.005
4	0.009	0.25	0.05	10.0	0.05	5.2	0.05	0.09	1.64	5.1	7.83	0.002
8	0.012	0.23	0.02	9.5	0.05	4.3	0.04	0.11	1.76	6.3	7.90	0.001
12	0.014	0.22	0.03	9.5	0.04	3.5	0.08	0.21	1.95	6.4	8.21	0.001
24	0.016	0.24	0.04	9.6	0.03	2.6	0.11	0.20	2.05	6.7	8.31	0.004
48	0.015	0.23	0.04	9.8	0.02	2.5	0.10	0.35	2.60	6.6	8.20	0.009
72	0.009	0.21	0.03	9.8	0.03	2.5	0.12	0.36	2.55	6.7	8.15	0.12
Original Sea water	0.03-0.24	0.05-0.8	0.1-0.8	0.4-3.0	0.03-0.15	0.4-3.0	0.02-0.75	0.03-0.12	0.2-0.5	6.8-8.0	7.8-8.0	0.00

All trace metals in ppb.

Sediment/seawater 1/20 by volume.

Water Quality of Soluble Phase in the Mixture of Compressed Air Aerated Seawater and Station A5 Sediment under Agitated Settling Conditions (Type E)

Time (hrs) Elapsed	Total Phosphorus	Phosphate	Kjeldahl Nitrogen	NH_3-N	Organic Nitrogen	Silicate	Temp. °C
0	0.034	0.030	0.144	0.013	0.101	2.0	25.0
0.5	0.285	0.260	0.538	0.86	0.452	8.65	25.0
1	0.140	0.126	0.361	0.09	0.352	9.20	25.1
2	0.045	0.050	0.376	0.08	0.296	10.10	25.3
4	0.040	0.035	0.400	0.09	0.391	9.30	25.0
8	0.035	0.031	0.480	0.085	0.395	7.30	25.0
12	0.040	0.040	0.541	0.060	0.481	8.95	25,2
24	0.045	0.030	0.588	0.070	0.518	10.10	25.2
48	0.040	0.025	0.629	0.065	0.564	11.20	24.8
72	0.040	0.030	0.713	0.068	0.645	12.15	25.0

All units in mg/l except temperature.

Table 12.11

COLUMN TEST SERIES
VI

Time (hrs) Elapsed	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	D.O. mg/l	pH	$S^=$ mg/l
0	0.035	0.25	0.15	15	0.130	1.2	0.09	0.11	0.40	7.2	7.8	0.007
0.5	0.021	6.0	0.03	1340	0.030	19.6	0.13	0.05	0.55	0.0	8.2	0.950
1	0.052	0.7	0.07	485	0.055	7.8	0.72	0.05	0.91	0.0	8.2	0.120
2	0.045	0.8	0.06	115	0.044	3.1	0.61	0.04	0.73	0.0	8.15	0.040
4	0.030	0.5	0.05	100	0.050	3.0	0.05	0.04	0.69	0.0	7.89	0.045
8	0.010	0.4	0.05	101	0.035	2.1	0.05	0.03	0.54	0.0	7.63	0.028
12	0.007	0.35	0.03	98	0.06	2.3	0.07	0.03	0.57	0.0	7.71	0.019
24	0.005	0.30	0.02	85	0.07	1.8	0.05	0.02	0.37	0.0	7.73	0.060
48	0.004	0.25	0.01	87	0.04	1.6	0.02	0.02	0.25	0.1	7.75	0.040
72	0.004	0.10	0.02	83	0.03	1.7	0.01	0.01	0.21	0.1	7.76	0.044
Original Sea water	0.03-0.24	0.05-0.8	0.1-0.8	0.4-3.0	0.03-0.15	0.4-3.0	0.02-0.75	0.03-0.12	0.2-0.5	6.8-8.0	7.8-8.0	0.00

All trace metals in ppb.

Sediment/seawater 1/20 by volume.

Water Quality of Soluble Phase in the Mixture of Seawater and Station C8 Sediment under Quiescent Settling Conditons (Type A)

Time (hrs) Elapsed	Total Phosphorus	Phosphate	Kjeldahl Nitrogen	NH_3-N	Organic Nitrogen	Silicate	Temp. °C
0	0.05	0.030	0.134	0.030	0.104	1.85	23.5
0.5	1.095	0.870	0.640	0.185	0.455	11.05	23.5
1	0.510	0.475	0.451	0.105	0.346	12.35	23.4
2	0.415	0.405	0.594	0.135	0.457	10.16	23.9
4	0.400	0.378	0.682	0.150	0.532	9.95	23.6
8	0.510	0.490	0.713	0.145	0.568	7.88	23.1
12	0.450	0.430	0.714	0.143	0.571	10.08	23.4
24	0.425	0.408	0.759	0.138	0.621	16.75	23.0
48	0.415	0.395	0.782	0.132	0.650	16.70	23.3
72	0.420	0.410	0.772	0.130	0.642	15.80	23.4

All units in mg/l except temperature.

Table 12.12

COLUMN TEST SERIES
VII

Time (hrs) Elapsed	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	D.O. mg/l	pH	$S^=$ mg/l
0	0.32	0.40	3.7	6.5	0.065	0.10	5.50	2.1	5.35	0.30	8.0	0.04
0.5	0.14	1.00	2.5	10.1	0.040	0.40	5.20	1.15	6.90	0.0	8.1	3.98
1	0.10	1.00	0.3	86	0.035	0.85	4.90	0.88	5.95	0.0	8.0	4.75
2	0.09	1.00	0.1	9.8	0.040	0.70	4.90	0.55	5.70	0.0	7.98	3.76
4	0.04	0.95	0.05	10.1	0.038	0.55	4.72	0.50	4.85	0.0	7.95	5.35
8	0.002	0.70	0.04	35	0.035	0.34	4.35	0.46	3.74	0.0	7.96	5.51
12	0.002	0.75	0.03	26	0.032	0.32	3.05	0.44	2.90	0.0	7.57	5.45
24	0.002	0.40	0.03	9.3	0.025	0.70	4.30	0.43	2.20	0.0	7.68	5.13
48	0.001	0.35	0.01	10.3	0.020	0.60	2.97	0.41	0.3	0.0	7.70	4.80
72	0.001	0.40	0.01	7.5	0.021	0.65	4.05	0.40	0.2	0.0	7.65	4.10
Original Sea water	0.03-0.24	0.05-0.8	0.1-0.8	0.4-3.0	0.03-0.15	0.4-3.0	0.02-0.75	0.03-0.12	0.2-0.5	6.8-8.0	7.8-8.0	0.00

All trace metals in ppb.

Sediment/seawater 1/20 by volume.

Water Quality of Soluble Phase in the Mixture of Deaerated Seawater and Station C8 Sediment under Quiescent Settling Conditions (Type B)

Time (hrs) Elapsed	Total Phosphorus	Phosphate	Kjeldahl Nitrogen	NH_3-N	Organic Nitrogen	Silicate	Temp. °C
0	0.015	0.012	0.145	0.030	0.115	1.10	23.0
0.5	0.675	0.563	0.866	0.370	0.496	16.05	22.8
1	0.610	0.615	0.680	0.250	0.430	15.10	23.1
2	0.615	0.547	0.761	0.290	0.471	14.20	22.7
4	0.603	0.551	0.870	0.245	0.625	12.90	23.2
8	0.597	0.576	0.865	0.252	0.613	13.57	22.5
12	0.600	0.558	0.868	0.265	0.603	11.98	22.9
24	0.585	0.563	0.887	0.245	0.642	12.01	23.1
48	0.580	0.559	0.904	0.240	0.664	12.20	22.8
72	0.582	0.560	0.911	0.210	0.701	13.10	22.5

All units in mg/l except temperature.

Table 12.13

COLUMN TEST SERIES
VIII

Time (hrs) Elapsed	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	D.O. mg/l	pH	$S^=$ mg/l
0	0.65	0.41	3.80	6.0	0.168	0-20	3.0	3.9	9.55	7.6	8.15	0.07
0.5	0.60	0.40	1.32	24.5	0.145	2.10	3.6	1.17	9.3	0.0	7.98	0.10
1	0.25	0.36	1.20	160	0.152	0.82	0.9	0.98	10.1	0.0	7.95	0.073
2	0.35	0.30	1.51	148	0.137	0.95	1.0	3.12	5.75	0.0	7.89	0.075
4	0.20	0.23	0.98	128	0.127	0.90	0.9	0.56	10.0	0.0	7.82	0.075
8	0.20	0.74	1.12	120	0.127	0.94	0.5	0.90	2.9	0.0	7.74	0.065
12	0.15	0.36	0.43	115	0.115	1.00	0.6	1.13	0.9	0.0	7.90	0.063
24	0.09	0.54	0.39	107	0.109	1.54	0.5	0.93	2.1	0.0	7.65	0.101
48	0.06	0.55	0.41	88	0.035	0.56	0.4	0.89	3.0	0.1	7.70	0.104
72	0.05	0.35	0.51	125	0.030	0.51	0.3	0.4	1.4	0.0	7.60	0.105
Original Sea water	0.03-0.24	0.05-0.8	0.1-0.8	0.4-3.0	0.03-0.15	0.4-3.0	0.02-0.75	0.02-0.12	0.2-0.5	6.8-8.0	7.8-8.0	0.00

All trace metals in ppb.

Sediment/seawater 1/20 by volume.

Water Quality of Soluble Phase in the Mixture of Compressed Air Aerated Seawater and Station C8 Sediment under Quiescent Settling Conditions (Type C)

Time Elapsed	Total Phosphorus	Phosphate	Kjeldahl Nitrogen	NH_3-N	Organic Nitrogen	Silicate	Temp. °C
0	0.030	0.014	0.290	0.05	0.240	2.0	19.8
0.5	0.465	0.443	0.585	0.195	0.390	11.03	20.3
1	0.431	0.414	0.511	0.160	0.351	12.50	20.0
2	0.450	0.440	0.543	0.162	0.381	10.90	20.0
4	0.447	0.432	0.613	0.160	0.453	11.0	20.1
8	0.470	0.451	0.704	0.150	0.554	9.1	20.2
12	0.465	0.448	0.775	0.135	0.640	8.9	21.0
24	0.480	0.461	0.805	0.130	0.675	12.30	20.8
48	0.474	0.452	0.715	0.133	0.582	13.50	21.0
72	0.460	0.445	0.654	0.134	0.520	13.70	20.5

All units in mg/l except temperature.

Table 12.14

Water Quality of Soluble Phase in the Mixture of Deaerated Seawater and Sta C_8 Sediment under Agitated Settling Conditions (Type D)

COLUMN TEST SERIES IX

Time (hrs) Elapsed	Ag	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	D.O. mg/l	pH	$\Sigma S^=$ mg/l
0		0.08	0.50	5.50	11.0	0.23	0.51	2.9	3.0	7.0	0.3	8.61	0.05
0.5		0.08	0.50	1.15	1620	0.04	1.3	3.4	2.9	6.8	0.1	8.64	0.05
1		0.07	0.46	0.89	230	0.03	1.2	2.1	3.4	6.3	0.1	8.70	0.06
2		0.10	0.47	1.43	190	0.10	1.0	1.4	3.3	5.9	0.0	8.58	0.06
4		0.09	0.47	1.35	175	0.12	1.4	1.1	4.0	5.7	0.0	8.81	0.07
8		0.15	0.50	1.30	154	0.05	1.1	0.7	2.3	6.3	0.0	8.78	0.07
12		0.13	0.49	1.25	30.0	0.07	1.0	1.2	1.5	6.4	0.0	8.83	0.05
24		0.12	0.47	1.50	23.0	0.06	1.05	0.8	1.8	6.2	0.0	8.82	0.04
48		0.13	0.48	1.64	27.0	0.05	1.0	1.6	1.7	6.3	0.0	8.80	0.04
72		0.10	0.45	1.51	35.0	0.04	1.2	1.4	1.6	6.2	0.0	8.90	0.04
Original Seawater	0.00-0.02	0.03-0.24	0.05-0.8	0.1-0.8	0.4-3.0	0.03-0.15	0.4-3.0	0.02-0.75	0.03-0.12	0.2-0.5	6.8-8.0	7.8-8.0	0.00

All trace metals in ppb.

Sediment/seawater ~1/20 by volume.

Time Elapsed	Total Phosphorus	Phosphate	Kjeldahl Nitrogen	NH_3-N	Organic Nitrogen	Silicate	Temp. °C
0	0.10	0.08	0.190	0.020	0.170	2.1	18.5
0.5	0.232	0.201	0.257	0.016	0.241	21.1	18.5
1	0.334	0.293	0.215	0.017	0.198	19.6	18.4
2	0.345	0.323	0.263	0.016	0.247	17.5	18.1
4	0.329	0.290	0.415	0.020	0.395	16.3	17.9
8	0.331	0.310	0.593	0.025	0.568	15.9	18.2
12	0.316	0.297	0.742	0.061	0.681	16.4	18.0
24	0.328	0.315	0.808	0.048	0.760	17.3	18.3
48	0.312	0.289	0.793	0.060	0.733	16.4	18.3
72	0.300	0.285	0.750	0.055	0.695	16.8	18.4

All units in mg/l except temperature.

Table 12.15

Water Quality of Soluble Phase in the Mixture of Compressed Air Aerated Sta C_8 Sediment under Agitated Settling Conditions (Type E)

COLUMN TEST SERIES X

Time (hrs) Elapsed	Ag	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	D.O. mg/l	pH	$\Sigma S^{=}$ mg/l
0		0.012	0.52	0.20	10.5	0.050	0.5	0.02	0.41	0.3	6.8	7.87	0.03
0.5		0.004	0.93	0.08	10.6	0.080	1.5	0.06	0.0	1.95	0.0	7.86	0.004
1		0.005	0.26	0.03	125	0.090	10.0	0.08	0.03	1.90	0.0	7.85	0.004
2		0.004	0.24	0.04	12.0	0.060	7.15	0.05	0.04	1.85	0.3	7.83	0.005
4		0.012	0.25	0.05	11.0	0.050	6.16	0.04	0.09	1.76	3.5	7.86	0.002
8		0.014	0.27	0.02	10.0	0.051	5.05	0.04	0.12	1.81	5.2	7.90	0.002
12		0.016	0.26	0.03	11.0	0.035	4.35	0.05	0.13	1.90	6.3	7.93	0.009
24		0.018	0.23	0.05	10.8	0.030	3.80	0.07	0.20	2.0	6.5	8.22	0.006
48		0.010	0.25	0.04	10.7	0.040	2.90	0.10	0.25	2.01	6.7	8.15	0.012
72		0.009	0.21	0.04	10.5	0.035	2.60	0.10	0.35	0.54	6.7	8.14	0.015
Original Seawater	0.00-0.02	0.03-0.24	0.05-0.8	0.1-0.8	0.4-3.0	0.03-0.15	0.4-3.0	0.02-0.75	0.03-0.12	0.2-0.5	6.8-8.0	7.8-8.0	0.00

All trace metals in ppb.

Sediment/seawater ~ 1/20 by volume.

Time Elapsed	Total Phosphorus	Phosphate	Kjeldahl Nitrogen	NH_3-N	Organic Nitrogen	Silicate	Temp. °C
0	0.040	0.025	0.130	0.020	0.110	2.10	23.0
0.5	0.300	0.278	0.556	0.100	0.456	10.02	23.0
1	0.160	0.142	0.490	0.105	0.385	9.89	23.6
2	0.050	0.043	0.388	0.094	0.299	10.40	23.1
4	0.040	0.030	0.485	0.095	0.390	8.75	23.0
8	0.040	0.025	0.544	0.081	0.463	8.28	22.9
12	0.045	0.028	0.571	0.075	0.496	9.79	22.5
24	0.040	0.040	0.631	0.068	0.563	10.10	22.8
48	0.040	0.032	0.734	0.070	0.664	11.30	23.0
72	0.040	0.035	0.750	0.070	0.680	11.80	23.0

All units in mg/l except temperature.

TABLE 12.21

Metal Release Compared with Standards
All values in ppb.

Element	Avg. Column test value (48 hr) at 1:20 dilution		Proposed EPA criteria (1975)	CSWRCB Stds. (1972)		Drinking water Standards (1962)	
	Low	High		50%	100% of time	Max.	Recv.
Ag	0.007	0.022	5000	20	40	50	--
Cd	0.105	0.155	100	20	30	10	--
Cr	0.325	0.441	100	5	10	50	--
Cu	0.15	0.746	—	200	300	*	1000
Fe	42.8	447.9	300	—	—	—	300
Hg	0.045	0.1311	100	1	2	—	—
Mn	0.830	1.298	100	—	--	—	—
Ni	0.774	1.772	100	—	--	—	—
Pb	0.272	0.994	50	100	200	—	--
Zn	1.586	3.490	1 - 200	300	500	*	5000

*same as recommended

Table 12.22

Water Quality in Water Column Without Polymer Treatment

(Station C8 Sediment)

All units in ppm unless specified.

Factors / Time	D.O.	Turbidity	Suspended Solids	pH	$\Sigma S^{=}$
5 min.	3.8	260	725	7.9	0.0
0.5 hr.	1.1	95	170	7.9	0.0
1 hr	5.0	80	110	7.0	0.0
2 hr.	5.1	55	70	7.9	0.0
4 hr.	5.2	32	46	7.8	0.0
12 hr.	5.0	26	36	7.7	0.0
24 hr.	5.0	8	36	7.8	0.0
48 hr.	5.0	7	35	7.7	0.0
72 hr.	5.0	7	35	7.7	0.0
CSWRCB Limit	---	50	50	---	---

Table 12.22, continued

Total Concentrations of Trace Metals in Water Column Without Polymer Treatment

(Station C8 Sediment)

All units in ppb.

Element \ Time	5 min	.5 hr	1 hr	2 hr	12 hr	24 hr	48 hr	72 hr	CSWRC Require
Cd	6.3	4.2	3.4	3.0	2.6	2.4	2.1	2.1	20
Cu	95	75	52	35	25	22	20	20	20
Cr	8.0	7.5	6.0	4.0	3.0	2.6	0.8	0.7	5
Fe	630	610	590	560	516	500	190	165	---
Mn	72	37	31	19	12	10	7.8	7.0	---
Ni	16	3.8	3.0	1.6	1.1	1.0	Trace	Trace	100
Pb	45	16	9	6	1.9	1.6	1.0	1.0	100
Zn	21	17	15	13	9.1	8.1	6.2	5.1	300

Table 23

Water Quality in Water Column After Treatment of 1:4 Sediment-Seawater Mixture with Polymer.

Anionic Polymer: WT-3000 (Station C8 sediment)

Factors / Time	DO	Turbidity	Suspended Solids	pH	$\Sigma S^{=}$
5 min.	4.1	43	335	7.9	0.0
30 min	5.3	24	85	7.9	0.0
1 hr.	5.4	17	59	7.9	0.0
2 hr.	5.4	11	27	7.9	0.0
4 hr.	5.5	10	24	7.9	0.0
12 hr.	5.5	8	25	7.8	0.0
24 hr.	5.4	7	19	7.8	0.0
48 hr.	5.4	7	19	7.8	0.0
72 hr.	5.4	7	19	7.8	0.0
SCWRCB Limit	---	50	50	---	---

All units in ppm unless specified.

Total Concentration of Trace Metals in Water Column after Treatment of 1:4 Sediment-Water Mixture with Polymer. (Station C8 Sediment)

Anionic Polymer: WT-3000
Polymer Dosage: 10 ppm

Time / Element	5 min.	30 min.	1 hr.	2 hr.	12 hr.	24 hr.	48 hr.	72 hr.	CSWRCB Req't.
Cd	6.5	4.0	2.0	2.0	1.9	1.9	1.8	1.8	20
Cu	78	46	15	14	15	14	14	14	20
Cr	5.8	3.9	2.2	1.5	1.4	1.0	0.8	0.8	5
Fe	645	596	535	460	410	395	180	175	--
Mn	68	25	9.3	9.0	8.1	7.8	8.0	7.8	--
Ni	15	3.4	1.0	0.9	0.5	0.4	T	T	100
Pb	28	5.0	3.8	2.1	1.4	1.4	1.0	1.8	100
Zn	19	13	7.0	5.0	4.8	4.6	4.1	4.1	300

All units in ppb. T = Trace

Table 24

Water Quality in Water Column after Treatment of 1:4 Sediment-Seawater Mixture with Polymer.

(Station C8 sediment)

Cationic Polymer: CAT-FLOC T

Factors / Time	DO	Turbidity	Suspended Solids	pH	$\Sigma S^{=}$
5 min.	4.6	82	282	7.9	0.0
30 min.	5.4	37	85	7.9	0.0
1 hr.	5.4	26	63	7.9	0.0
2 hr.	5.5	11	45	7.9	0.0
4 hr.	5.5	10	40	7.9	0.0
12 hr.	5.4	9	36	7.9	0.0
24 hr.	5.4	8	32	7.9	0.0
48 hr.	5.1	6	28	7.9	0.0
72 hr.	5.2	6	28	7.9	0.0
CSWRCB Limit	---	50	50	---	---

All units in ppm unless specified.

Total Trace Metals Concentration in Water Column after Treatment of 1:4 Sediment-Water Mixture with Polymer. (Station C8 sediment)

Cationic Polymer: CAT-FLOC T
Polymer Dosage: 10 ppm

Time / Element	5 min.	30 min.	1 hr.	2 hr.	12 hr.	24 hr.	48 hr.	72 hr.	CSWRCB Req't.
Cd	4.8	4.0	2.8	2.0	1.9	1.9	1.4	1.4	20
Cu	92	42	20	16	14	11	11	11	20
Cr	6.0	5.4	3.6	1.6	1.2	0.7	0.7	0.7	5
Fe	635	630	520	485	456	400	180	175	--
Mn	65	28	16	10	9.8	9.5	9.0	9.0	--
Ni	13	3.0	1.4	1.1	0.8	0.5	T	T	100
Pb	26	5.0	2.1	1.4	1.2	1.0	1.0	1.0	100
Zn	19	15	11	7.5	5.2	4.2	4.2	4.1	300

All units in ppb. T = Trace

Table 12.25

Results of Jar Test for the Selection of Optimum Dosage of Flocculants

(Station C8 Sediment)

Anionic Polymer: WT-3000

Cationic Polymer: CAT-FLOC T

Type / Polymer Dosage	CAT-FLOC T (Cationic Polymer)		WT-3000 (Anionic Polymer)	
	Suspended Solids (ppm)	Turbidity (ppm)	Suspended Solids (ppm)	Turbidity (ppm)
0 ppm	215	80	226	82
1 ppm	92	25	75	19
2 ppm	51	21	50	17
4 ppm	39	20	36	14
10 ppm	22	13	31	13
20 ppm	16	13	20	13

*Sediment/Seawater = 1:4

Standard Jar Test requires rapid mixing of flocculant at 100 rpm for 5 minutes followed by slow mixing at 20 rpm for 20 minutes and 10 minutes of settling.

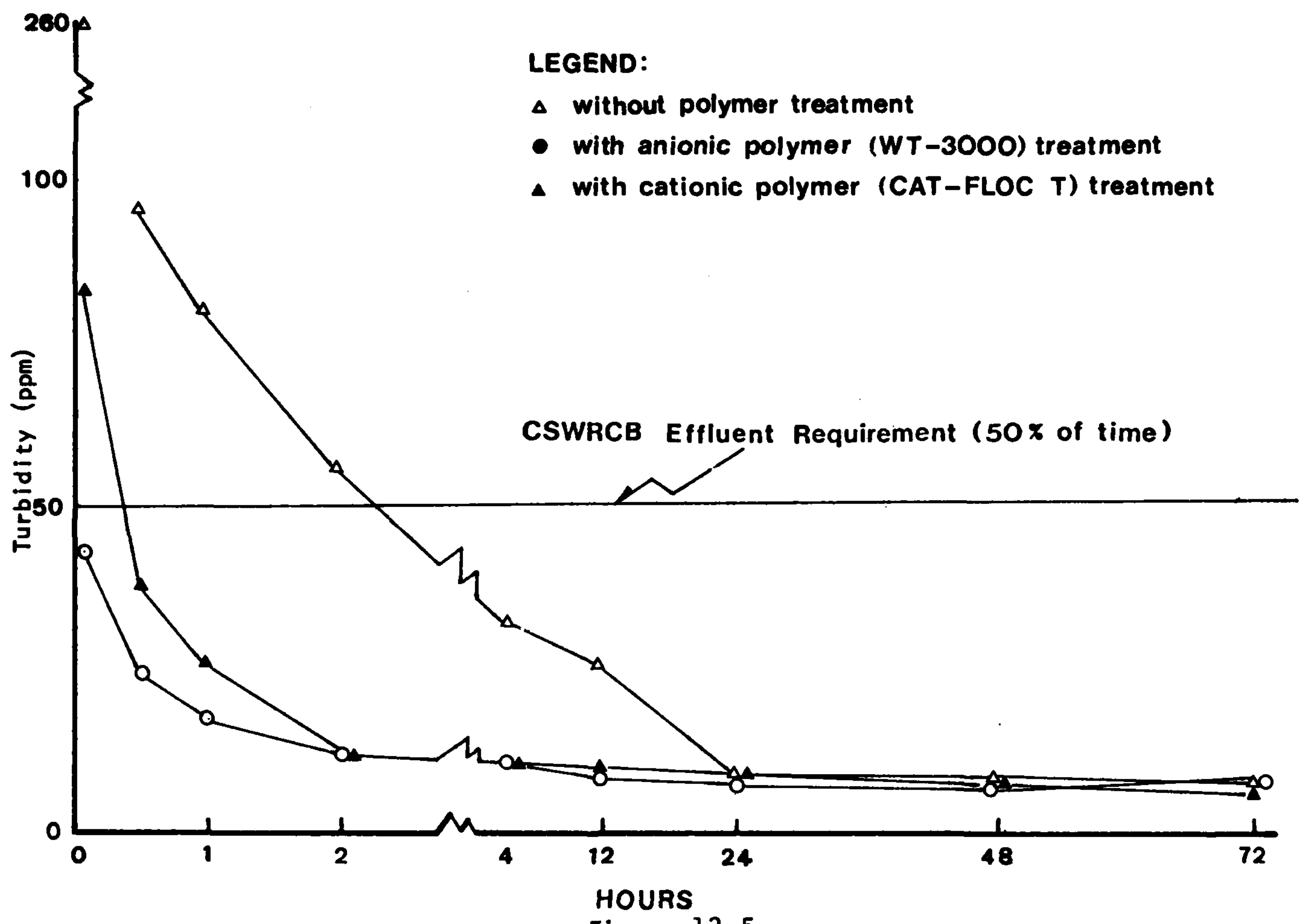


Figure 12.5

Total Turbidity in the Water Column under Different Treatment Conditions

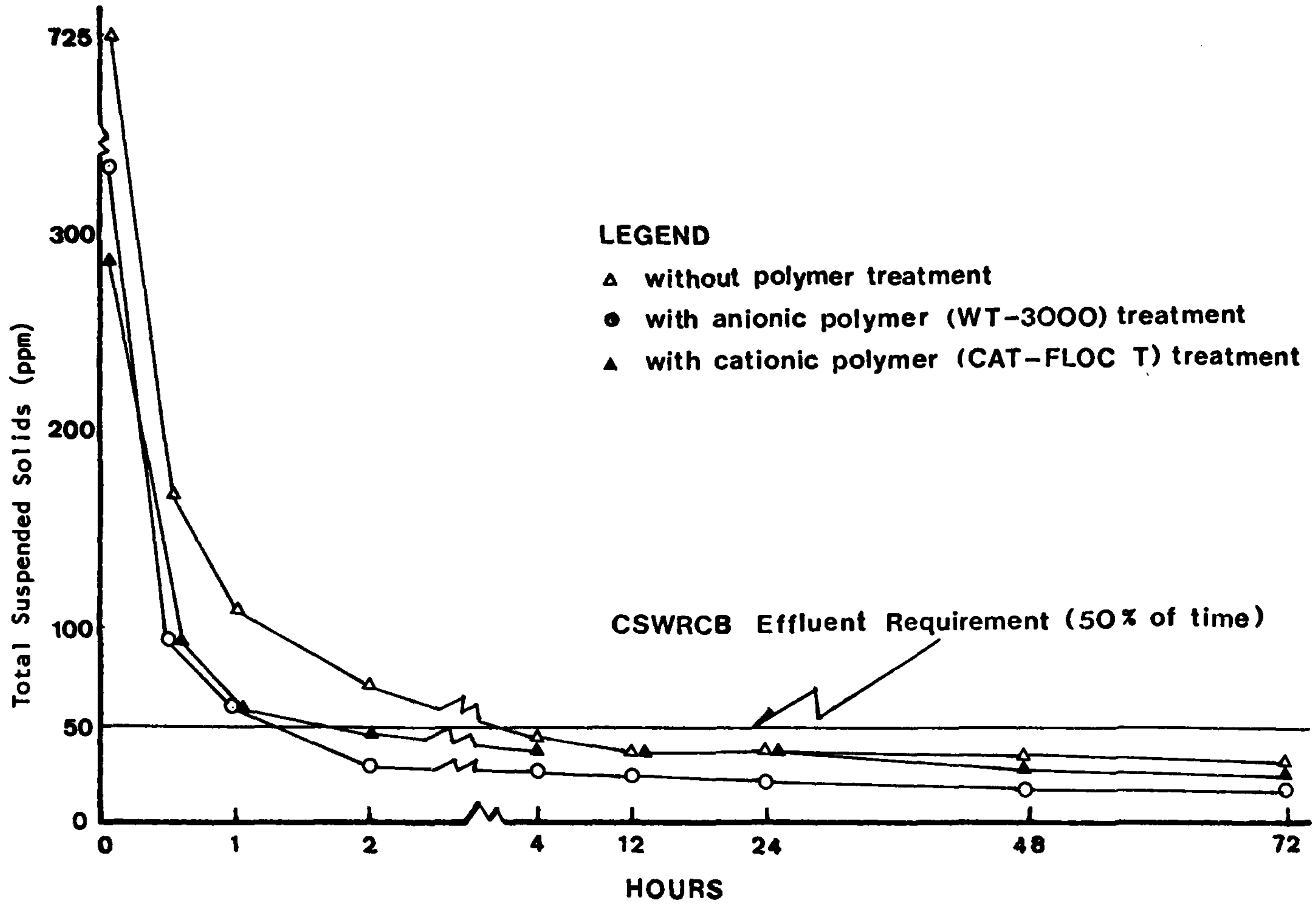


Figure 12.6

Total Suspended Solids in the Water Column under Different Treatment Conditions

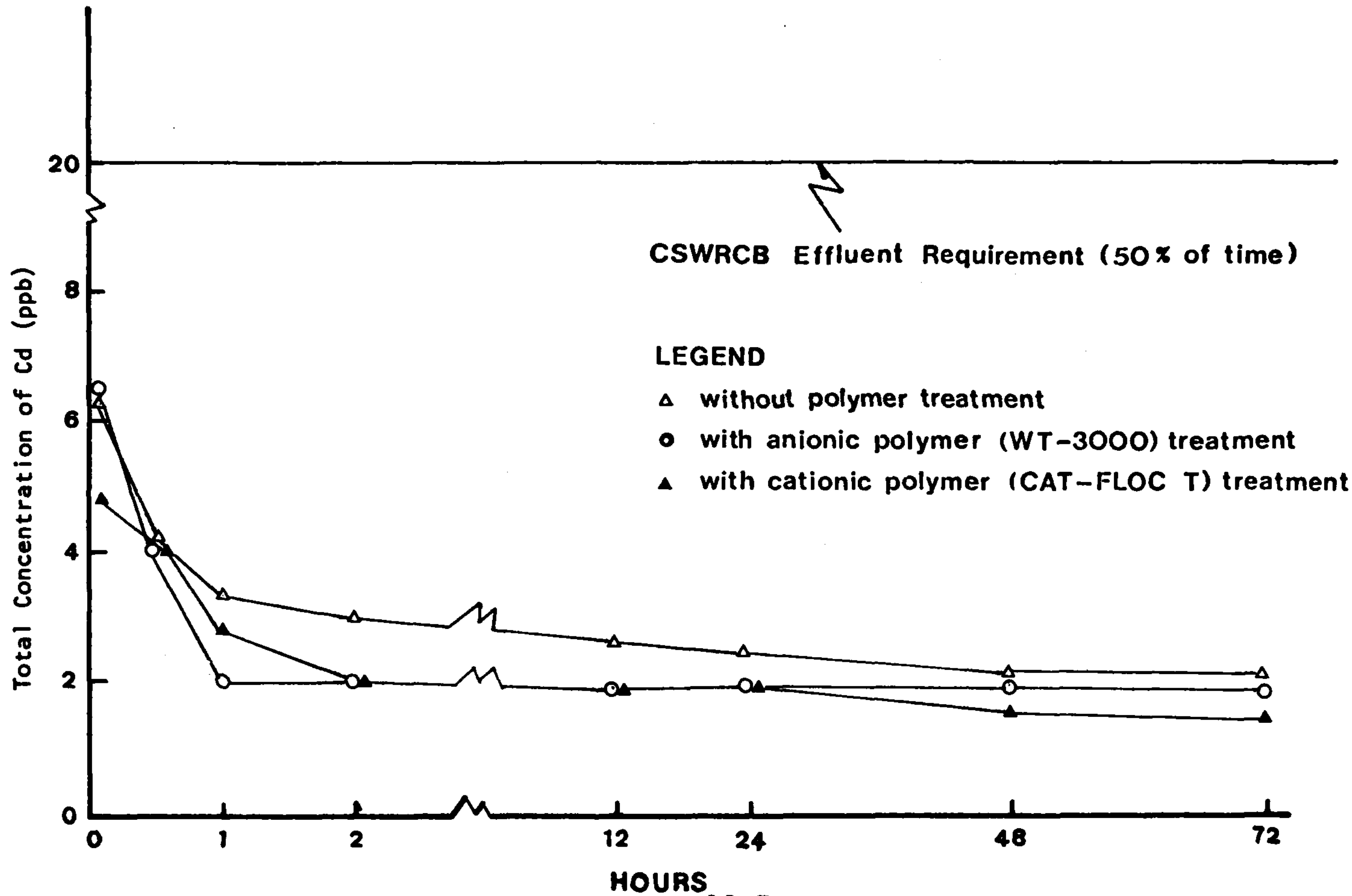


Figure 12.7

Total Concentration of Cd in the Water Column under Different Treatment Conditions

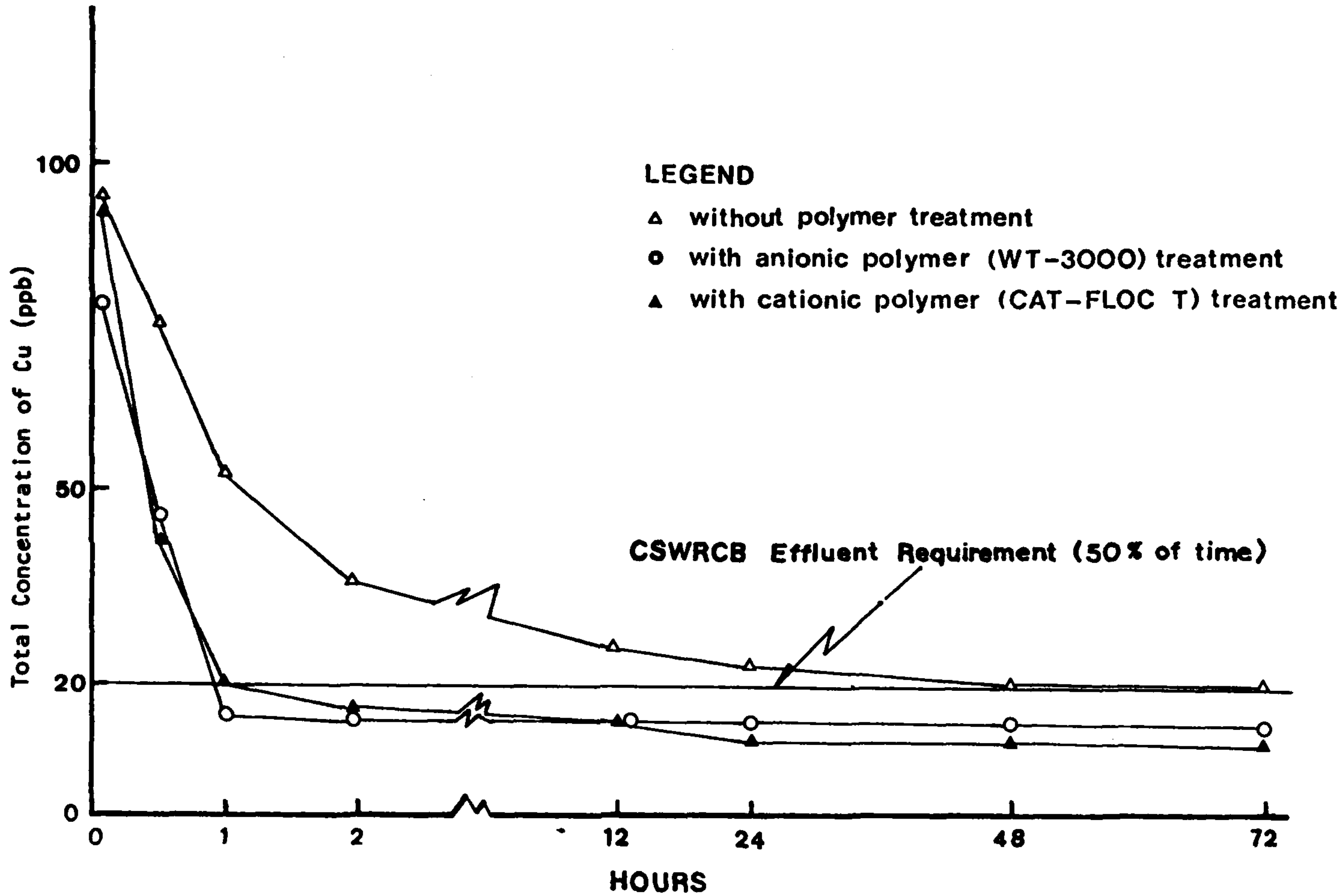


Figure 12.8

Total Concentration of Cu in the Water Column under Different Treatment Conditions

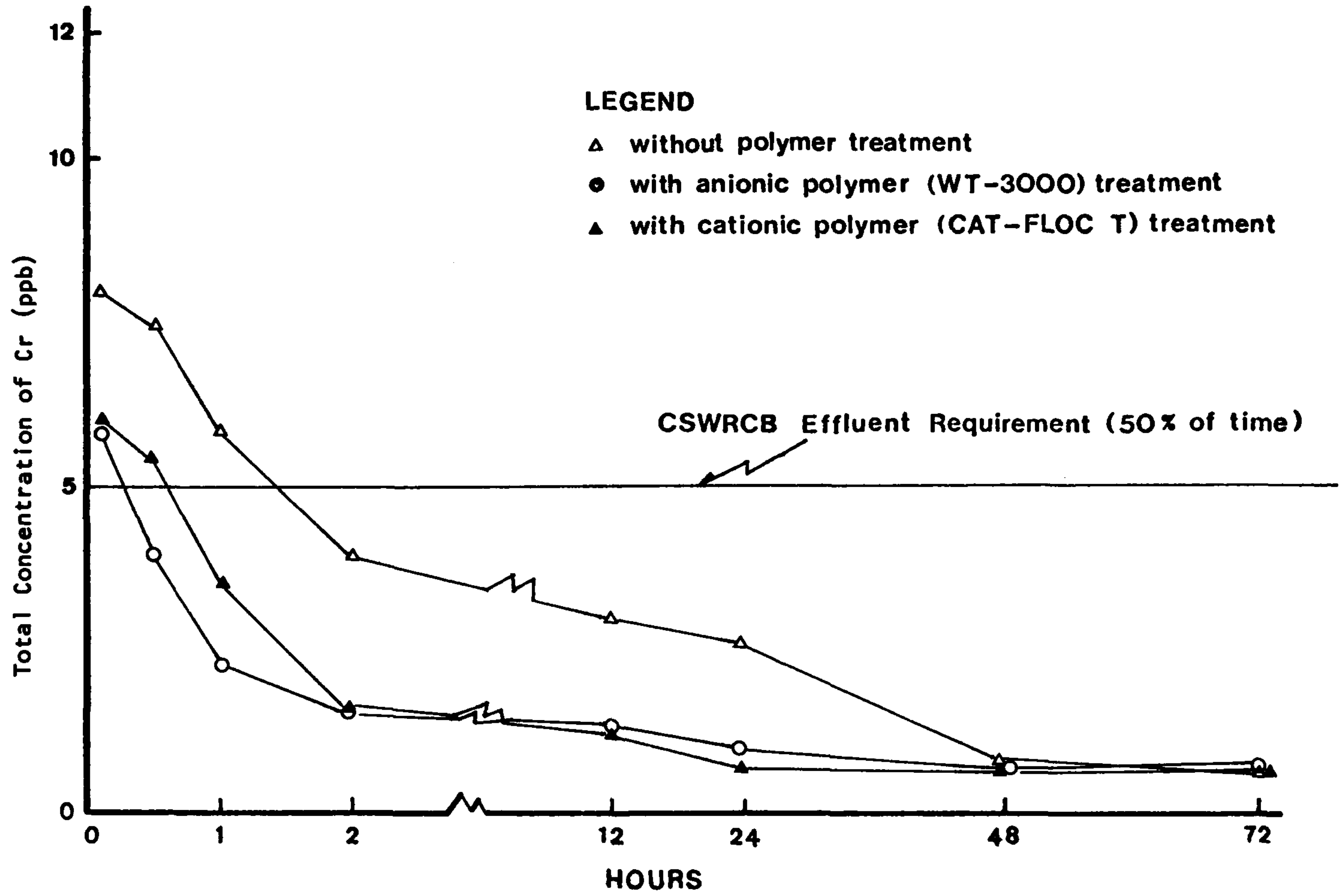


Figure 12.9

Total Concentration of Cr in the Water Column under Different Treatment Conditions

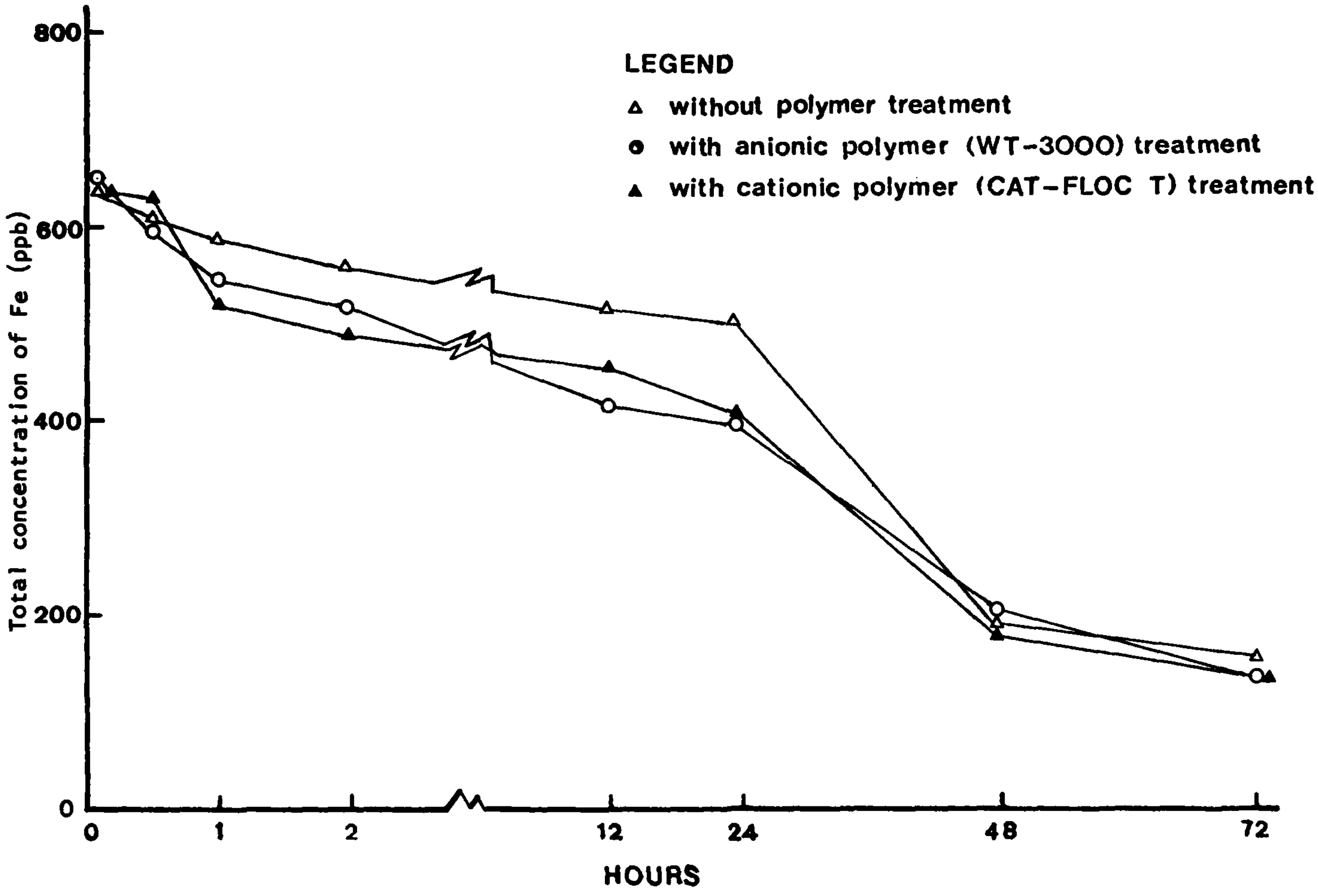


Figure 12.10

Total Concentration of Fe in the Column under Different Treatment Conditions

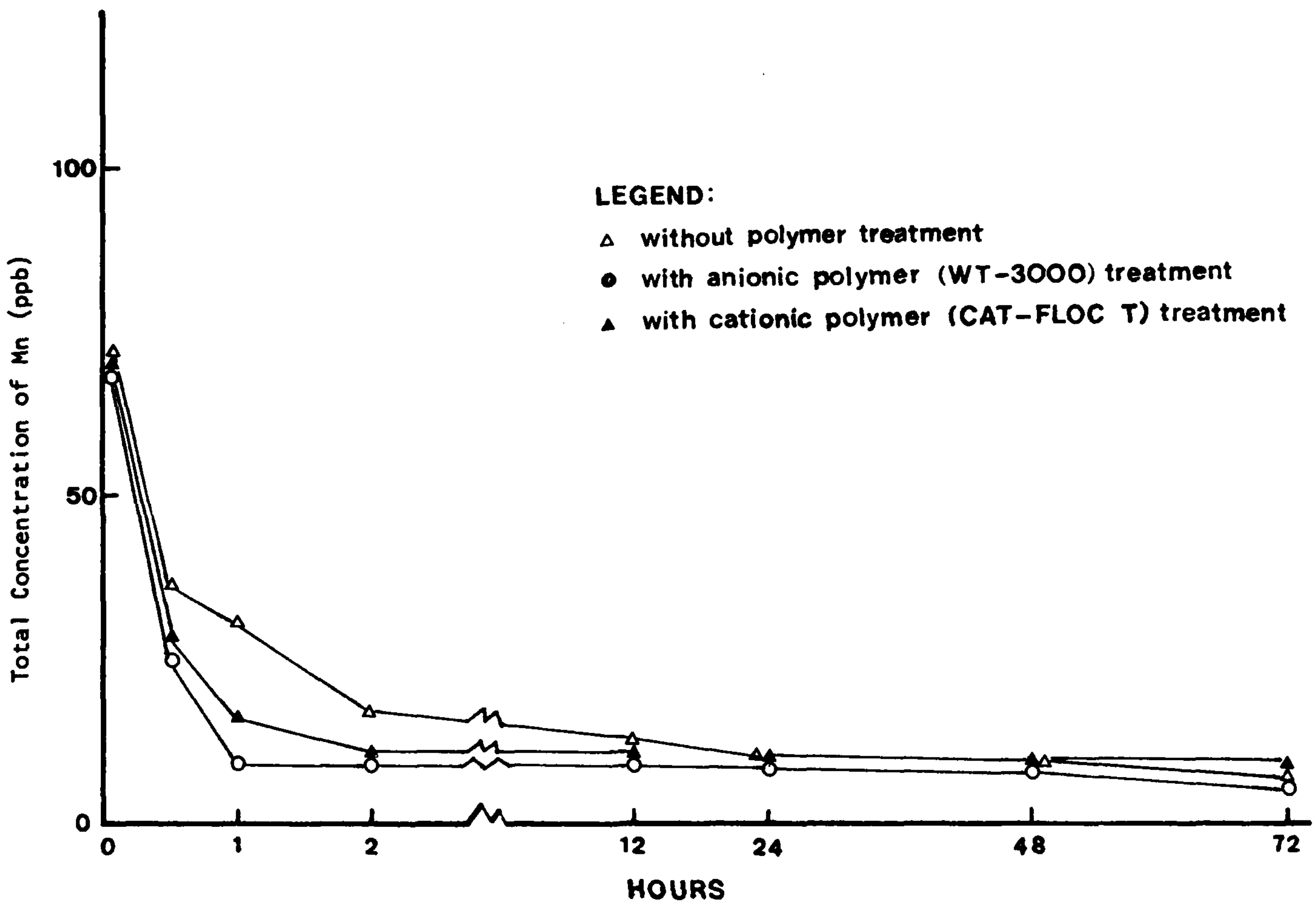


Figure 12.11

Total Concentration of Mn in the Water Column under Different Treatment Conditions

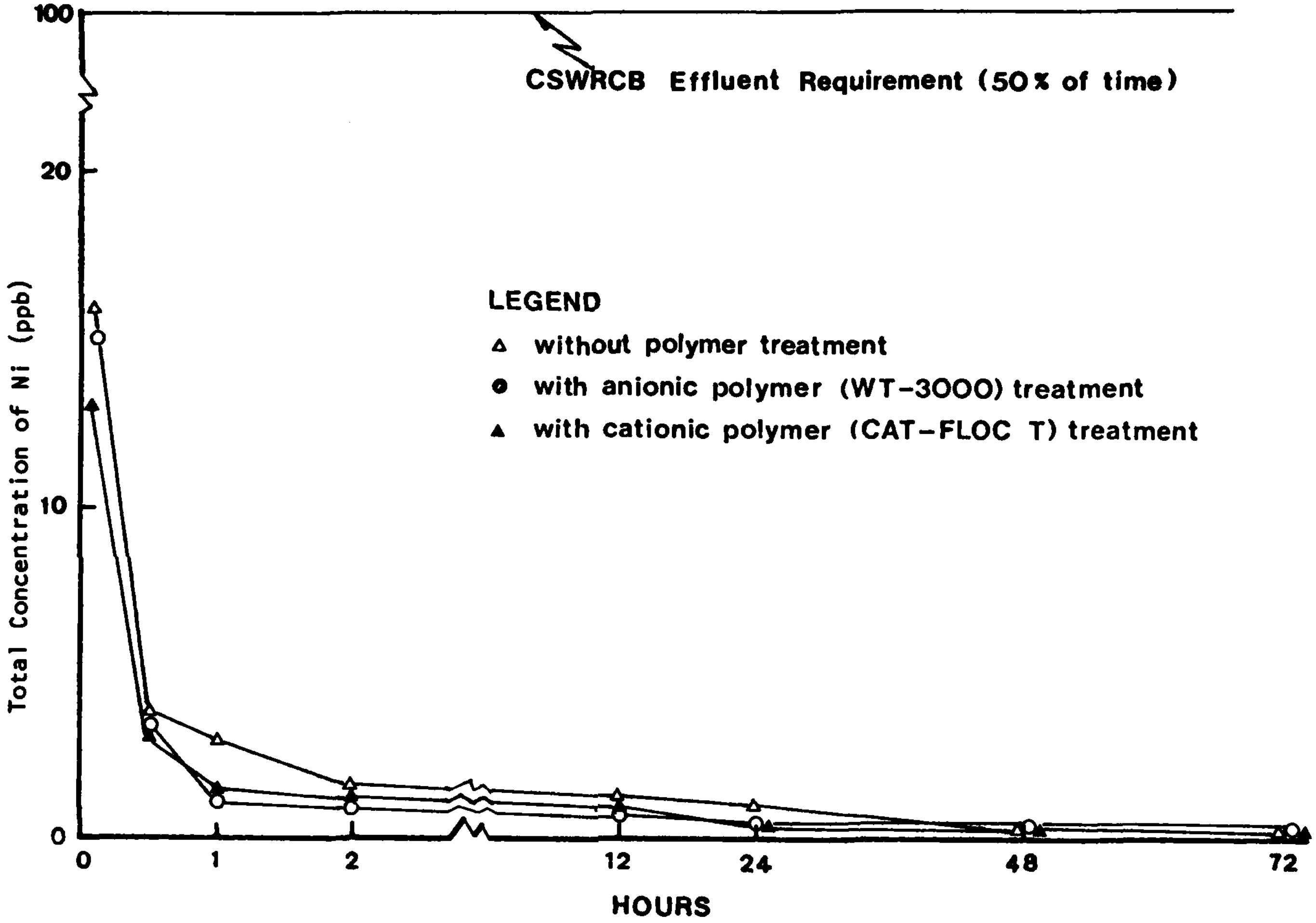


Figure 12.12

Total Concentration of Ni in the Water Column under Different Treatment Conditions

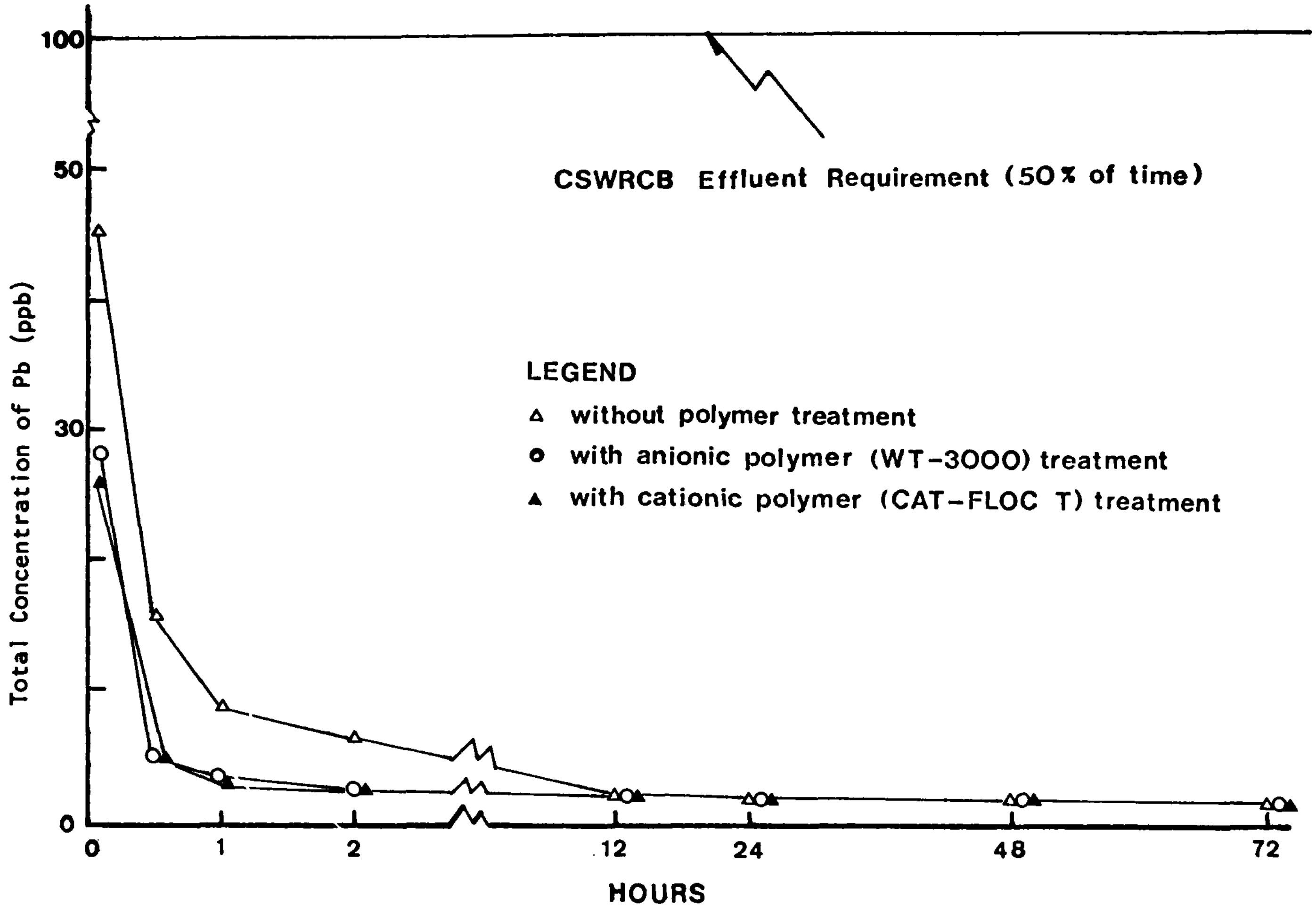


Figure 12.13

Total Concentration of Pb in the Water Column under Different Treatment Conditions

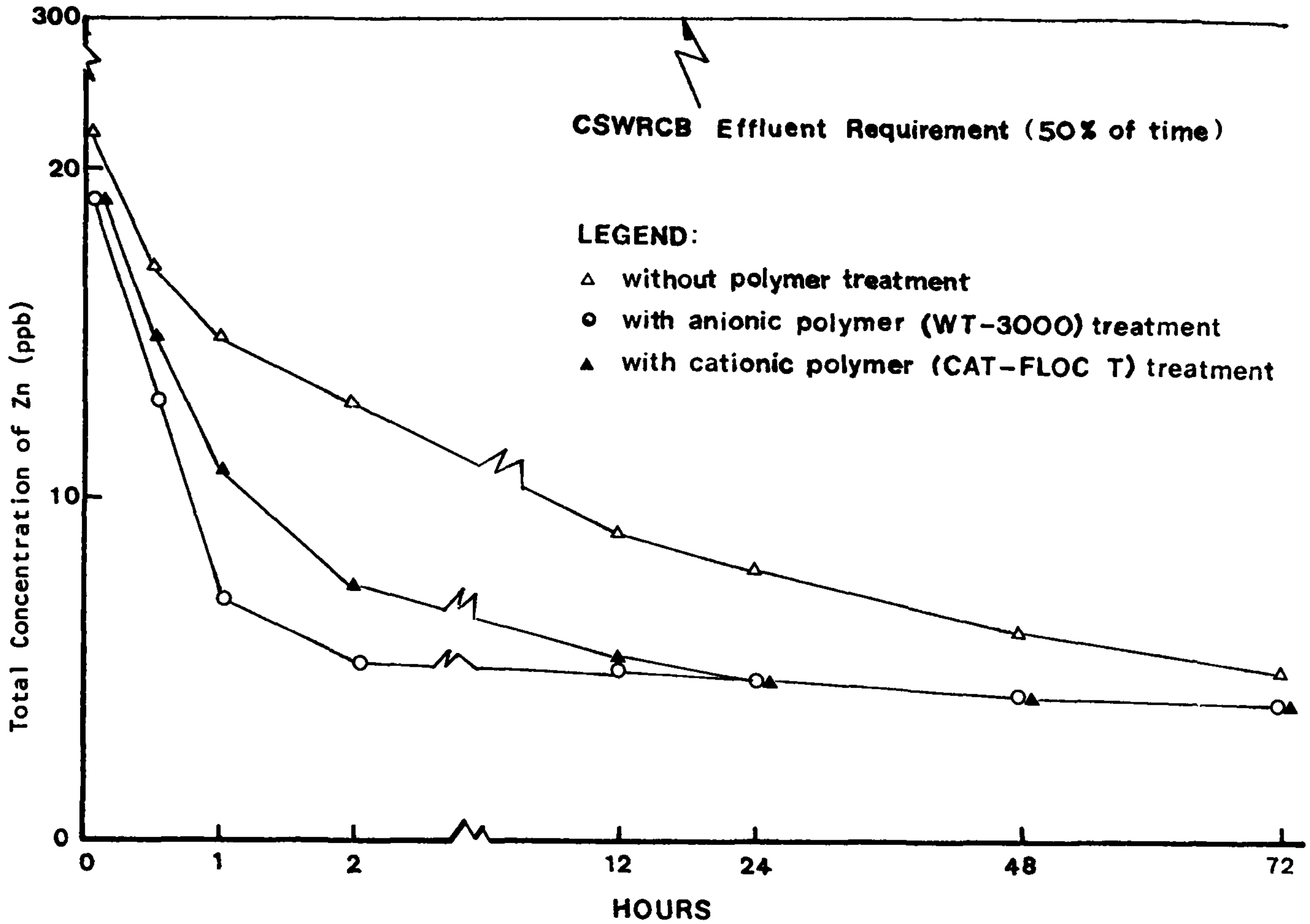
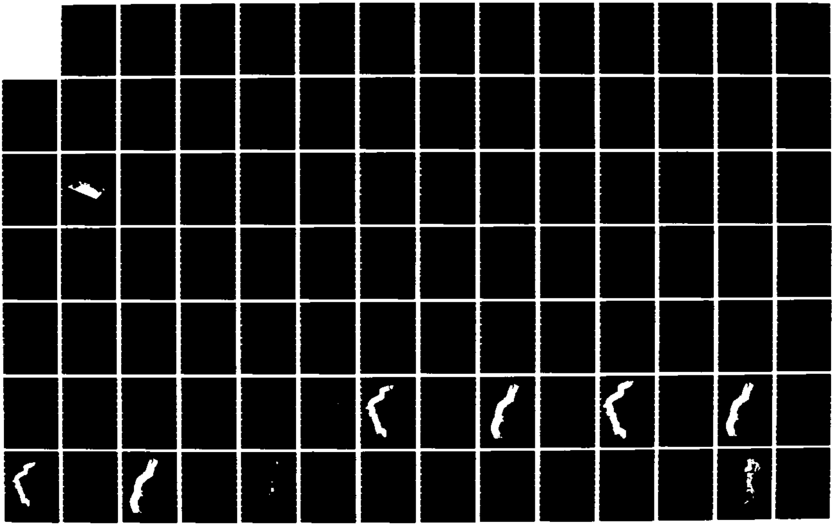


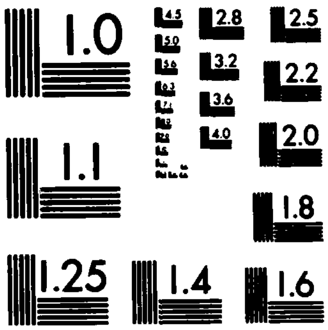
Figure 12.14

Total Concentration of Zn in the Water Column Under Different Treatment Conditions

AD-A136 653 ENVIRONMENTAL INVESTIGATIONS AND ANALYSES FOR LOS ANGELES-LONG BEACH HARB..(U) UNIVERSITY OF SOUTHERN CALIFORNIA LOS ANGELES ALLAN HANCOCK F.. DEC 76 7/8

UNCLASSIFIED DACW09-73-C-0112 F/G 8/10 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

LITERATURE CITED

American Public Health Association. 1971. Standard methods for the examination of water and wastewater, 13th ed. New York.

Argaman, Y. and C.L. Weddle. 1973. Fate of heavy metals in physical-chemical treatment processes. American Institute of Chemical Engineering Symposium Series 136, 70: 400-414.

Armstrong, F.A.J., R.J. Williams and J.D.H. Strickland. 1966. Photo-oxidation of organic matter in seawater by ultra-violet radiation--analytical and other applications. Nature, 211: 481-484.

Barnard, W.M. and M.J. Fishman. 1973. Evaluation of the use of the heated graphite atomizer for the routine determination of trace metals in water. Atomic Absorption Newsletter, 12 (5): 118-124.

Bass-Becking, L.G.M., I.R. Kaplan and D. Moore. 1968. Limits of the natural environment in terms of pH and oxidation-reduction potentials. Journal of Geology, 68: 243-284.

Bear, F.E. (ed.) 1964. Chemistry of the soil, 2nd ed., American Chemical Society Monograph Series No. 160, Reinhold Pub. Co., New York.

Blum, B.E., R.O. Murrman and D.C. Leggett. 1974. The direct and indirect effects of sediment organic fractions on the migration and bioavailability of various contaminants during dredging and disposal of sediments. ODMR No. Y130-1C03, US Army Corps of Engineers, New Hampshire.

Boyd, M.B., R.T. Saucier, J.W. Keeley, R.L. Montgomery, R.D. Brown, D.B. Matheus and C.J. Guice. 1972. Disposal of dredge spoil. Tech. Report No. H-72-8, US Army Corps of Engineers WES, Vicksburg, Mississippi .

Brooks, R.R., B.J. Presley and I.R. Kaplan. 1967. APDC-MIBK extraction system for the determination of trace elements in saline waters by atomic absorption spectrophotometry. Talanta, 14: 809-816.

Brooks, R.R., B.J. Presley and I.R. Kaplan. 1968. Trace elements in the interstitial waters of marine sediments. Geochimica et Cosmochimica Acta, 32: 307-414.

Burrell, D.C. 1968. Atomic absorption spectrophotometry in the field of marine research. Atomic Absorption Newsletter 7(4):65-68.

Burton, J.D. and P.L.Liss. 1973. Processes of supply and removal of dissolved silicon in the oceans. Geochimica et Cosmochimica Acta 37:1761-1773.

California State Water Resources Control Board. 1972. Water quality control plan, ocean waters of California. Resolution No. 72-45.

Chen, K.Y. 1974. Chemistry of sulfur species and their removal from water supply. In Chemistry of Water Supply, Treatment and Distribution. Ann Arbor Science Publishers, Inc.

Chen, K.Y., S.K.Gupta, A.Z.Sycip, J.S.Lu, M.Knezevic. 1975. Effect of dispersion, settling, and resedimentation on migration of chemical constituents during open water disposal of dredged materials. Report to U.S.Army Corps Engineers Waterways Experiment Station, Vicksburg, Ms.

Chen, K.Y. and J.C.S.Lu. 1974. Sediment composition in Los Angeles-Long Beach Harbors and San Pedro Bay. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 4. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles.

Chen, K.Y. and J.C.Morris. 1972. Oxidation of sulfide by O_2: Catalysis and inhibition. J. San. Engin. Div., ASCE 98 (SA1):215.

Chen, K.Y. and C.C.Wang. 1974. Physiochemical results of elutriate tests of sediments from the proposed LNG route. Report to Board of Harbor Commissioners, City of Los Angeles.

Chen, K.Y. and C.C.Wang. 1975. Water quality effects and treatments of returned effluents from a diked disposal area. Report on Agreement No. 1000, Board of Harbor Commissioners, City of Los Angeles.

Chen, K.Y. and C.C.Wang. 1975. Feasibility study of treatment of dredge spoils. Report on Extra Work Order, Agreement No. 1000, Board of Harbor Commissioners, City of Los Angeles.

Chen, K.Y. and B.Eichenberger. 1976. Concentrations of trace elements in marine fish. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 11. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. Appendix.

Chen, K. and C.C.Wang. 1976. Water quality evaluation of dredged material disposal from Los Angeles Harbor. In Marine

Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 11. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 155-236.

Dudas, M.J. 1974. Effect of drying parameters on the heated graphite furnace determination of trace metals in MIBK-APDC solutions. Atomic Absorption Newsletter 13:67-69.

Dyrssen, D. 1972. Inorganic chemicals. In A Guide to Marine Pollution. E.D.Goldberg, ed. Gordon and Breach Science Publishers, New York.

Ediger, R.D. 1973. A review of water analysis by atomic absorption. Atomic Absorption Newsletter 12(6):152-157.

Ediger, R.D., G.E. Peterson and J.D.Kerber. 1974. Application of the graphite furnace to saline water analysis. Atomic Absorption Newsletter 13(3):61-64.

Emerson, R.R. 1974. Preliminary investigations on the effects of resuspended sediment on two species of benthic polychaetes from Los Angeles Harbor. In Marine Studies of San Pedro Bay, California. Part 3. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 97-110.

Emerson, R.R. 1976. Bioassay and heavy metal uptake investigations of resuspended sediment on two species of polychaetous annelids. In *Marine Studies* of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 11. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 69-90.

Environmental Protection Agency. 1971. Criteria for determing acceptability of dredged spoil to the nation's waters.

Environmental Protection Agency. 1971. Ocean dumping criteria. Federal Register 38(198):12872-12877.

Environmental Protection Agency. 1973. Ocean dumping: final regulations and criteria. Federal Register 38(198):28610-28621.

Environmental Protection Agency. 1973. Dredge spoil disposal criteria.

Environmental Protection Agency. 1973. Proposed criteria for water quality. Volume I.

Environmental Protection Agency. 1974. Interim dredge spoil disposal criteria. Revision I.

Jenne, E.A. 1968. Controls on Mn, Fe. Co, Ni, Cu, and Zn concentrations in soils and water: The significant role of hydrous Mn and Fe oxides in trace inorganics in water. R.F.Gould, ed. Amer. Chem. Soc. Publ., Washington, D.C.

Joyner, T. 1967. Proconcentration for trace analysis of sea water. Environ. Sci. and Tech. I:417-424.

Keeley, J.W. and R.M.Engler. 1974. Discussion of regulatory criteria for ocean disposal of dredged materials: Elutriate test rationale and implementation guidelines. Misc. Paper D-74-14, U.S.Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Krauskopf, K.B. 1956. Factors controlling the concentration of thirteen rare metals in seawater. Geochimica et Cosmochimica Acta 9:1-32B.

Krauskopf, K.B. 1967. Introduction to geochemistry. McGraw-Hill, New York.

Krenkel, P.A., J.Harrison and J.C.Burdick, III. 1976. Dredging and its environmental effects. Proc. Spec. Conference, Mobile, Ala. Amer. Soc. Civil. Engin. c. 1037 p.

Lee, G.F. and R.H.Plumb. 1974. Literature review on the research study for the development of dredged material disposal criteria. U.S.Army Corps of Engineers, Contract No. DACW 39-74-C-0024, Vicksburg, Miss. 145 p.

Macfarlane, I.C. 1974. Predredging study clears LNG ships berth plan. World Dredging and Marine Construction 42.

May, E.B. 1973. Environmental effects of hydraulic dredging in estuaries. Alabama Marine Resources Bull. 9:1-85.

Moore, J.R., III. 1963. Bottom sediment studies, Buzzards Bay, Mass. J. Sed. Petrol. 33:511-558.

Nair, K.P. and A. Cottenie. 1971. A statistical evaluation of the inter-relationship between particle-size fractions, free iron oxide, and trace elements. J. Soil Sci. 22: 201-209.

Nix, J. and T.Goodwin. 1970. The simultaneous extraction of iron, manganese, copper, cobalt, nickel, chromium, lead and zinc from natural water for determination by atomic absorption spectroscopy. Atomic Absorp. Newsletter 9(6): 119-122.

Odum, E.P. 1971. Fundamentals of Ecology. 3rd ed. W.B.Saunders and Co., Philadelphia.

Omang, S.H. 1971. Determination of mercury in natural waters and effluents by flameless atomic absorption spectrophotometry. Analytica Chimica Acta, 53: 415-420.

Paus, P.E. 1973. Determination of some heavy metals in seawater by atomic absorption spectrophotometry. Journal of Analytical Chemistry, 264: 118-122.

Perkin-Elmer Co. 1971. Analytical methods for atomic spectrophotometry. Manual No. EN-2.

Presley, B.J., Y. Kolodny, A. Nissenbaum and I.R. Kaplan. 1972. Early diagenesis in a reducing fjord, Saanich Inlet, British Columbia--II. Trace element distribution in interstitual water and sediment. Geochimica et Cosmichimica Acta, 36: 1073-1090.

Riley, J.P. and D. Taylor. 1968. Chelating resins for the concentration of trace elements from seawater and their analytical use in conjunction with atomic absorption spectrophotometry. Analytica Chimica Acta, 40: 479-485.

Robertson, D.E. 1968. Role of contamination in trace element analysis of seawater. Analytical Chemistry, 40: 1067-1072.

Rubin, A.J. 1975. Control mechanisms of trace metals in aqueous environmental chemistry of metals. Ann Arbor Science Publishers.

Segar, D.A. 1971. The use of the heated graphite atomizer in marine sciences. Third International Congress of Atomic Absorption and Atomic Fluorescence Spectrometry. Paris.

Segar, D.A. and J.G. Gonzales. 1972. Evaluation of atomic absorption with a heated graphite atomizer for the direct determination of trace transition metals in seawater. Analytica Chimica Acta, 58: 7-14.

Siegel, A. 1971. Metal-organic interactions in the marine environment. Organic Compounds in Aquatic Environments, Ed. by S.J. Faust and J.V. Hunter. Marcel Dekker, Inc., New York.

Stumm, W. and G.F. Lee. 1961. Oxygenation of ferrous iron. Industrial and Engineering Chemistry, 53: 143.

Stumm, W. and J.J. Morgan. 1970. Aquatic chemistry. Wiley-Interscience, New York.

Wakeman, T.H. 1974. Mobilization of heavy metals from re-suspended sediments. American Chemical Society Annual Conference, Atlantic City, New Jersey.

Willey, B.F., C.M. Duke, A.L. Wajcieszak and C.T. Thomas. 1972. Atomic absorption spectrophotometer simplifies heavy metals analysis. American Water Works Association Journal, 64: 303-306.

Windom, H.L. 1972. Environmental aspects of dredging in estuaries. Journal of the American Association of Civil Engineering, 98 (WW4): 475-487.

Zobell, C.E. 1946. Studies on the redox potential of marine sediments. Bulletin of the American Association of Petrochemistry and Geology, 30: 477-514.

APPENDIX I

Direct Injection Procedures.

1. Extract 500 ml seawater with 25 ml of MIBK and 5 ml of 1% APDC (previously shaken with equal amounts of MIBK and separated to remove all traces of heavy metals.

2. Equilibrate for 30 min. and separate in a funnel.

3. Repeat steps #1 and 2 for the lower aqueous layer.

4. Transfer equal amounts of extracted seawater to clean bottles.

5. Add increasing increments of stock standard solution.

6. Add ultrapurified HNO_3 to keep metals in soluble phase.

7. Inject seawater samples and standard with the aid of an Eppendorf micropipette into the graphite tube furnace for salt interferences.

8. Compare the absorbances from the samples with those of known standards (calibration curve) and compute for sample concentration.

APPENDIX II

APDC-MIBK Extraction.

1. Take 100 ml of acidified sample and adjust pH to around 4.0 with NaOH.

2. Add 7 ml of MIBK and 1 ml of 1% APDC (previously shaken with equal amounts of MIBK and separated).

3. Equilibrate on a Burnell wrist shaker Model #75 for 30 minutes.

4. Transfer to a separatory funnel; save all lower aqueous layers for use in standard preparation. Transfer upper MIBK layer to clean sample bottle and save for subsequent AA analysis.

5. Take 500 ml of the aqueous layer from Step #4, re-extract twice, each time using 25 ml of MIBK and 5 ml of 1% APDC.

6. Shake vigorously and separate into layers with a separatory funnel.

7. Prepare several 100 ml extracted seawater portions and add increasing increments of stock standard solutions.

8. Proceed as described in Steps #2 - 4, but use 5 ml of MIBK to compensate for the MIBK in the extracted seawater (solubility of MIBK approximately 2% at room temperature).

9. Inject MIBK extracts (samples and standards) into the graphite tube furnace of the AA spectrophotometer with an Eppendorf micropipette.

10. The APDC-MIBK extracts stay stable for only a limited time, so the following order of element analysis has been followed:

    Zn, Cd, Ni., Pb, Ag, and Cu

11. Compare absorbances from samples with those of known standards (calibration curve) and compute for sample concentration.

APPENDIX III

Mercury Determination.

1. Set up sparging system and glassware.

2. Adjust flow of nitrogen carrier gas to 150 mm on flowmeter.

3. Take desired amount of sample.

4. Add 5 ml of 1:4 H_2SO_4 and 1 ml of 2% $KMnO_4$.

5. Add drop-wise 10% of hydroxylamine hydrochloride until solution turns colorless.

6. Add 2 ml of 10% $SnCl_2 \cdot 2H_2O$ solution.

7. Immediately connect flask to sparging unit and pass N_2 gas by switching both stopcocks simultaneously.

8. Measure response in recorder for about 2 minutes.

9. Repeat similar procedures (Steps #2 - 8) for blanks.

10. Calculate sample concentration by comparing against peak areas obtained from standard mercury solution.

Chapter 13

SUBTIDAL ALGAE AND MACROFAUNA FROM THE BREAKWATERS:

INTERTIDAL BEACH STUDIES

SUBTIDAL ALGAE AND MACROFAUNA FROM THE BREAKWATERS: INTERTIDAL BEACH STUDIES

INTRODUCTION

No baseline studies of the flora and fauna of the Los Angeles-Long Beach Harbors breakwaters had been published prior to the survey carried out in 1973 for the U.S.Army Corps of Engineers (Setzer, 1974). Prior to that time, Dawson (1959, 1965a, 1965b) and Widdowson (1971) had studied the area of Point Fermin, to the west of San Pedro, and Dawson (1965a) reported a study by Setchell and Gardiner made near the turn of the century.

Subsequently, Harbor Environmental Projects (1976) tabulated algae collected and identified by Setzer for the summer of 1974, and compared the two years. In addition, the macrofauna from the 1974 collections were identified and tabulated.

Algae and associated organisms were collected from 12 stations (H stations, Figure 13.1) along the three breakwaters protecting the Los Angeles-Long Beach Harbors during July and August of 1973 and 1974 (see Table 13.1 for collection dates). Divers with SCUBA gear sampled each station at about the 3 meter depth. A one square-meter quadrat was scraped to remove all algae, and associated invertebrates; however, the emphasis was on sampling the algae.

Identifications of either fresh or preserved (5% formalin/seawater) specimens were made in the laboratory. Voucher specimens of all organisms were retained.

Three beaches in the harbor area were studied by Straughan and Patterson (1975), who surveyed the intertidal fauna at inner Cabrillo Beach (Los Angeles Harbor), outer Cabrillo Beach (outside the breakwater), and the City of Long Beach (near the lifeguard station at the end of Junipero Street).

DISCUSSION

There were considerable differences between the 1973 and the 1974 algae collections. Although the relative totals are similar, the species composition changed extensively (see Table 13.2). This may have been due to changes in ocean temperatures between the two years, as documented in Soule and Oguri (1974, 1976).

The algae found in the two years are presented in Table 13.2, with symbols indicating the year of occurrence. The organisms found in the study are listed in Table 13.3. A total of 85 species of algae were identified for the two summer collection periods. Blue-green algae and diatoms were purposefully omitted. Close to 40 taxa of invertebrates were reported.

The majority of algae species were the small, epiphytic types, many being microscopic in size. They were found primarily on *Prionitis lanceolata* and *Gelidium robustum*, which were the dominant species. The most abundant epiphytes are listed in Table 13.4. One point of interest is that many of these epiphytes were fully reproductive while being less than a centimeter in height. Other individuals of the same species have been observed to become reproductive after attaining not less than a height of 6-15 cm.

In general, the outside of the breakwaters appears richer in terms of species diversity (see Table 13.5). The lack of sufficient physical data makes it impossible to determine precisely why the outside of the breakwater is so rich. In the same sense, two species in the 1973 study were found only on the inside of the breakwater. It would appear that one or more factors are acting on the inside breakwater algae to limit growth there. Physical parameters such as lower temperatures, increased wave action, and increased circulation on the outside of the breakwater are important factors to consider. Pollutant levels, and grazing may also affect the incidences.

The fauna collected from the breakwater stations does not appear to fit any obvious pattern of occurrence. One explanation for this may be that sampling was done mainly for algae, and only the macroinvertebrates were collected. The other invertebrates were those found in the algae.

The area inside the breakwater at station H3 seemed to show the poorest algal crop, and no animals were found. This may be the area of poorest circulation, as it is not within the large gyre of the outer Los Angeles harbor area, nor is it directly flushed by the current at Queens Gate, Long Beach. Station H5, to the east of Queens Gate was richest in collected animals. Station H9 on the outside of the breakwater, opposite the depauperate H3, was the richest in algal species in the two summers.

The Straughan beach transects showed that considerable variation occurred in sand budget at the beaches during 1973-1974. This, coupled with air-water temperature differences, seem to govern the macrofauna present.

The three beaches showed very different biological communities, except for the complete absence of fauna above the high tide level. This may have been due to beach cleaning activities.

Outer Cabrillo is exposed to lower water temperatures, and greater sand and water movement; Inner Cabrillo and Long Beach are exposed to higher temperatures and lesser sand and water movement. The outer beach has a fauna more typical of coarser-grained sediment and open coast; the inner beaches were dominated by species typical of finer sediments and less wave action (Tables 13.6, 13.7; Figure 13.2).

Long Beach had reduced numbers of species and of organisms, which was not in keeping with the expectations for that substrate. Studies by Straughan (1973) of beaches that received heavy amounts of oil showed an abundance of species that were absent in Long Beach. It is possible that the intermittent flow from the Los Angeles River flood control channel, or pollutants carried by the channel, are responsible for the depauperate fauna.

LITERATURE CITED

Dawson, E.Y. 1959. A preliminary report on the benthic marine flora of southern California. In Oceanographic Survey of the Continental Shelf area of Southern California. Calif. State Water Poll. Contr. Bd., Publ. No. 20, pp. 169-264. Sacramento, California.

Dawson, E.Y. 1965a. Intertidal algae. In An Oceanographic and Biological Survey of the Southern California Mainland Shelf. Chapter VIII. State Water Quality Contr. Bd. Publ. No. 27, pp. 220-227. Sacramento, California.

Dawson, E.Y. 1965b. Intertidal algae stations. IBID. Table IXA. Appendix Data: 351-433.

Harbor Environmental Projects. 1976. Intertidal-subtidal surveys. In Master Environmental Setting. Volume II. Port of Long Beach Draft Environmental Impact Report.

Setzer, R. 1974. Preliminary investigations of benthic marine algae from the breakwaters protecting Los Angeles-Long Beach Harbors. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 4. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 89-101.

Soule, D. and M.Oguri. 1974. Data Report. Temperature, salinity, oxgyen, and pH in outer Los Angeles Harbor. June 1971 to November, 1973. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 5. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles.

Soule, D. and M.Oguri. 1976. Potential ecological effects of hydraulic dredging in Los Angeles Harbor: An overview. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 11. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 1-14.

Straughan, D. 1973. The influence of the Santa Barbara oil spill (January-February, 1969) on the intertidal distribution of marine organisms. Rpt. to Western Oil and Gas Assn. 77 p.

Straughan, D. and M.Patterson. 1975. Intertidal sandy beach macrofauna at Los Angeles-Long Beach Harbor. Part 1 and 2. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 8. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 75-107.

Widdowson, T.B. 1971. Changes in the intertidal algal flora of the Los Angeles area since the survey by E.Y.Dawson in 1956-1959. Bull. So. Calif. Acad. Sci. 70(1):2-16.

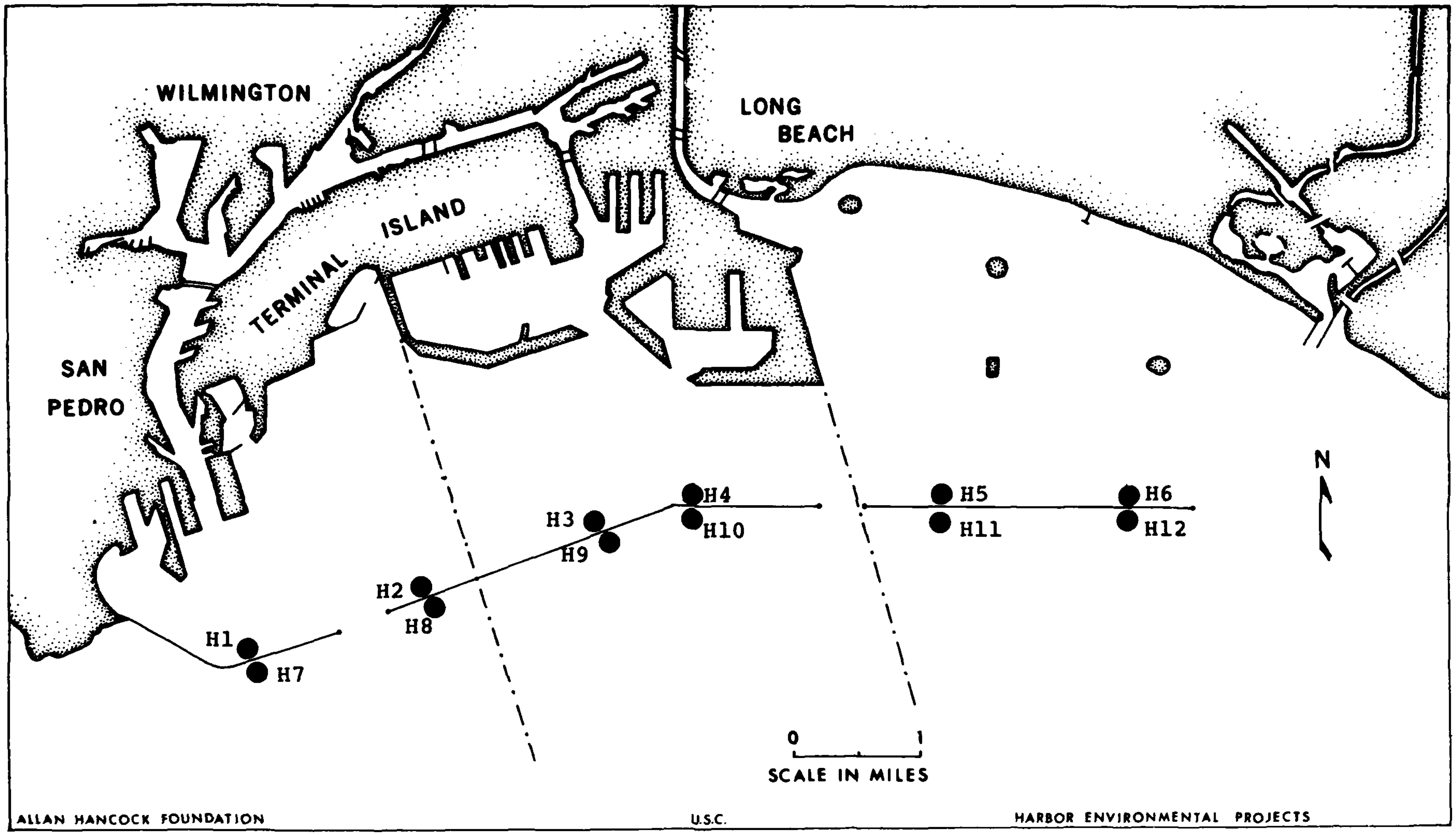


Figure 13.1. Diver Survey Algal Sampling Stations, Summer 1973 and 1974.

Table 13.1 . Collection Dates, Algal Sampling Survey.

Station	1973	1974
H1	July 23	July 19
H2	July 23	July 19
H3	July 30	July 26
H4	July 30	July 26
H5	July 30	August 1
H6	July 30	August 9
H7	August 7	August 1
H8	August 7	August 9
H9	August 21	August 16
H10	August 21	August 16
H11	August 27	August 23
H12	August 27	August 23

Table 13.2. Algae from breakwater, Los Angeles-Long Beach Harbors.

ALGAE	H STATIONS Inside Breakwater						Outside Breakwater					
	1	2	3	4	5	6	7	8	9	10	11	12
Chlorophycophyta												
Bryopsis sp.								●				
Chaetomorpha sp.	●							●				
Cladophora albida			△									
Cladophora graminea	△	●										
Cladophora sp.	●	△		△		●		●				
Derbesia marina		●					△	●				
Enteromorpha prolifera	△										△	
Enteromorpha sp.	●			●		●△		●	●			●
Ulothrix sp.											●	●
Ulothrix (?)									△		△	
Ulva californica												△
Ulva lobata						△						
Ulva sp.	△	△●	●	●	△	●		△●	△		● △	
Phaeophycophyta												
Colpomenia peregrina	●											
Dictyota flabellata	△								△			
Dictyota sp. (young)					●							
Ectocarpus spp.						●△			●		●	
*Egregia laevigata**												
Feldmannia sp.		△					△		●			●
Giffordia sp.	●△	●△			●△	●△		●	△●		△	●△
Pachydictyon coriaceum												△
Sphacelaria sp.								●	△			
Rhodophycophyta												
Acrochaetium sp.		△		△	●	●		●	●		● △	●△
Anisocladella pacifica	△	●										
Antithamnion defectum	△	●					●△	●△	●△	● △	● △	●△

● 1974 △ 1973 ○ Dominant alga in each station.

* - Not in quadrat, but in proximity.

Table 13.2. (cont'd)

ALGAE	H STATIONS: Inside Breakwater						Outside Breakwater					
	1	2	3	4	5	6	7	8	9	10	11	12
Antithamnion brevi-ramosa	● △											
Bangia sp.						●						
Binghamia forkii		●										
Bossiella orbigniana var. *orbigniana*										△	△	
Callithamnion sp.								△				△
Ceramium eatonianum				△							△	
C. pacificum									●			
C. zacae											△	
Chondria arcuata						●			△			△
Corallina officinalis var. *chilensis*							△		△			△
C. pinnatifolia	●	△●		△	△	△●	●		●△		△	
C. vancouveriensis	△●								●			
Cryptopleura corall-inara					●		● △	△	● △	● △	△	● △
C. crispa										●		
Cryptopleura sp.											●	
Dasya sinicola var. *abyssicola*	● △											
Erythrotrichia carnea									△			
Erythrotrichia sp.	△	●			●△	●	●		●		●	●
Fauchea laciniata var. *pygmaea*		●					● △		● △		△	△
Faucheocolax attenuata												△
Gelidium coulteri					△							
G. pusillum			●	●				●	●			●
G. robustum					△		△		△	△●	△●	●△
Gigartina armata/spinosa complex							△					
G. canaliculata				△								
G. leptorhynchos				△	△							△

● 1974 △ 1973 ◯ Dominant alga in each station.

Table 13.2. (cont'd)

ALGAE	STATIONS: Inside Breakwater 1	2	3	4	5	6	Outside Breakwater 7	8	9	10	11	12
Gigartina spinosa							●					
G. tepida	●	(△)●		●		△●	△	△●	△●		△●	△●
Gonimophyllum skottsbergii							△					
Goniotrichum cornu-cervi				△				△				
G. elegans	△	△	△	△	△	△	△	△	△		△	△
Goniotrichum sp.		●		●	●	●		●	●			●
Gymnogongrus platyphyllus				△			△					
Herposiphonia plumula var. *parva*									● △			
Laurencia pacifica (distichus form)					●	●						●
Lithothamnion sp.										△		
Lithothrix aspergillum	●											
Lomentaria baileyana						●						
Lophosiphonia villum			△					●	△			△
Microcladia coulteri	△	●		△	△		●△	△●	●△	●△	●	●△
Murrayellopsis dawsonii			△			●			△			
Nienburgia andersoniana	● △						●△			△		
Phycodrys profunda ?		●						●				
Pleonosporium abyssicola	● △							△	△	●		
Pogonophorella californica	△											
Polysiphonia pacifica var. *delicatula*	● △	● △		● △	● △	● △	● △	● △	● △	△	● △	● △
P. scopulorum								△			△	
Polysiphonia sp.						●			●			
Prionitis lanceolata	●(△)	●		(△)	(△)		●(△)	(△)●	●△	●△		●(△)
Pterocladia media		△	(△)						△			
Pterocladia media ?								●				

● 1974 △ 1973 ◯ Dominant alga at each station.

Table 13.2. (cont'd)

ALGAE	H STATIONS											
	Inside Breakwater						Outside Breakwater					
	1	2	3	4	5	6	7	8	9	10	11	12
Pterosiphonia baileyi										●		
P. dendroidea	●△	●△		△	△	●	△	△	●△		●△	●△
P. pennata	●											
Rhodoglossum affine		●		△	△							△
Rhodymenia californica	△			△					△			△
R. pacifica		△					●△					
Sorella delicatula							△					
Tiffaniella sp.								●△	△			
Veleroa subulata		●		●	●	●		●			●	
Totals 1973	20	13	5	15	14	8	21	14	27	10	18	23
Totals 1974	17	20	2	8	9	19	11	21	21	9	15	18

● 1973 △ 1974 ○ Dominant alga at each station.

Table 13.3 . Fauna from the Los Angeles-Long Beach Breakwater, 1974 H Stations.

SPECIES	STATIONS H1	H2	H4a	H5a	H6	H6a	H8	H9	H10
Coelenterata									
Eudendrium sp.		■							
Muricea (?)	■								
Obelia sp.				■					
Bryozoa									
Cauloramphus spiniferum			■						
Costazia sp.			■						
Crisia sp.				■					
Crisulipora occidentalis				■					
Fenestrulina malusi			■						
Filicrisia sp.				■					
Membranipora tuberculata							■	■	
Microporella californica				■					
Rhynchozoon rostratum			■						
Thalamoporella californica	■								
Tricellaria occidentalis				■					
Tubulipora concinna				■					
Mollusca									
Crepidula onyx		■							
Dialula sandiegensis			■						
Kelletia kelletii		■							
Molpalia mucosa			■						
Mytilus edulis								■	
Mytilus sp. (prob. *edulis*)							□		
Saxodomus nuttali		▲	■	▲					
Annelida									
Spirorbid worms			■	■					
Arthropoda									
Cancer sp.				□					
Caprella equilibra									■
Caprella sp.								■	
Pugettia producta								■	■
Pyromaia tuberculata	■						■		
Tetraclita squamosa rubescens		■	■						
Synidotea harfordi				■					
Amphipods				■					
Pycnogonid				■					

□ Immature ■ Present, adult ▲ Dead

Table 13.3. (cont'd). Fauna from the Los Angeles-Long Beach Breakwater, 1974 H Stations.

SPECIES	H1	H2	H4a	H5a	H6	H6a	H8	H9	H10
					STATIONS				
Echinodermata									
Patiria miniata					■	■			
Pisaster ochraceus					■			■	
Strongylocentrotus franciscanus							■		
Strongylocentrotus purpuratus					■				
Urochordata									
Ciona intestinalis			■						

□ **Immature** ■ **Present, adult** ▲ **Dead**

Station Totals	3	5	10	13	3	1	4	5	2

Table 13.4 . Abundant Algal Epiphytes.

Antithamnion defectum

Cryptopleura corallinara

*Fauchea laciniata f. pygmaea**

Goniotrichum elegans

*Microcladia coulteri**

Polysiphonia pacifica var. *delicatula**

*Pterosiphonia dendroidea**

*** Denotes species in which dwarfism was exihibited.**

Table 13.5. Exclusive Algal Species (present on one or the other side of the breakwaters).

Inside Breakwater

Bossiella orbigniana

Callithamnion sp.

Ceramium sp.

Chondria arcuata

Corallina officinalis var *chilensis*

Cryptopleura corallinara

Fauchea laciniata f. pygmaea

Polysiphonia scopulorum

Tiffaniella sp.

Ulothrix? sp.

Outside Breakwater

Cladophora sp.

Erythrotrichia sp.

Table 13.6. Monthly Beach Intertidal Data

Month	Number of Species			Number of Organisms			Survey Length (feet)			Low Tide Height (feet)		
	OC	IC	LB	OC	IC	LB	OC	IC	LB	OC	IC	LB
1973												
March	1	3	1	31	5*	1	190	210	180	-0.7	-0.8	-0.7
May	6	8	3	74	13*	7	260	200	170	-0.8	-0.4	-0.1
July	6	14	3	16	146	12	250	230	170	-1.0	-1.0	+0.4
Sept.	2**	11	3**	3	33	5	180	220	140	+0.1	+0.1	+0.1
Nov.	9	15	3	29	294	4	300	240	170	-0.7	-0.2	+0.4
1974												
January	10	10	3	33	114	4	180	240	200	-0.6	-0.6	-0.6
March	6	5	2	39*	8	5	160	200	170	+0.0	+0.0	+0.1
May	5	16	1	67*	130*	1	170	210	190	-0.2	-0.5	-0.7
July	3	6	1	23	7	1	200	190	170	+0.5	+0.5	+0.2

OC = Outer Cabrillo Beach; IC = Inner Cabrillo Beach; LB = Long Beach.

* = Grunion eggs (Leuresthes tenuis) not included; ** = Polychaete samples missing.

Table 13.7. Occurrence of Species at Each Site (1971 - 1974)

Species	Outer Cabrillo 1971-72	Outer Cabrillo 1973-74	Inner Cabrillo 1971-72	Inner Cabrillo 1973-74	Long Beach 1973-74
CRUSTACEA					
Allorchestes compressa				+	
Blepharipoda occidentalis	+	+			
Caprella brevirostris				+	
Caprella californica			+		+
Caprella verrucosa				+	
Cirolana chiltoni			+	+	
Emerita analoga	+	+	+	+	+
Heterophoxus sp.	+				
Isochelespilosus			+		
Lepidopa myops	+				
Paraphoxus epistomus		+			
INSECTA				+	
VERMES					
Capitella capitata			+		
Capitellidae	+		+		
Cirriformia spirabrancha			+	+	
Dispio sp.	+		+	+	
Eunicidae			+		
Euzonus dillonensis	+	+		+	+
Glycera convoluta			+	+	
Glycera branchiopoda			+	+	
Glycera tenuis				+	
Glyceridae	+	+	+	+	+
Hemipodus borealis	+		+	+	
Lumbrineris zonata	+		+	+	
Lumbrineridae	+	+	+	+	
Magelona pitelkai	+		+	+	
Magelonidae		+	+		
Nephtys californiensis	+		+		
Nephtys caecoides			+	+	
Nephtys ferruginea	+	+	+	+	+
Nephtys sp.	+	+	+	+	+
Nephtyidae	+	+	+	+	
Nerinides acuta	+	+	+	+	+
Nothria elegans				+	
Notomastus tenuis	+				
Notomastus sp.	+				
Orbiniidae sp.				+	
Spiophanes bombyx			+	+	
Spionidae	+	+		+	
Spiochaetopterus costarum				+	
Paranoides platybranchia	+		+		
Pectinaria californiensis			+		
Platynereis bicanaliculata					+
Unidentified species	+				
Annelid fragments	+	+			
Nemertea sp. A	+	+	+		
Nemertea sp. B		+		+	
Sipunculida			+		
MOLLUSCA					
Donax gouldii	+				+
Olivella biplicata		+	+	+	
Tivela stultorum	+	+			
PISCES					
Leuresthes tenuis		+		+	
TOTAL	26	18	29	29	9

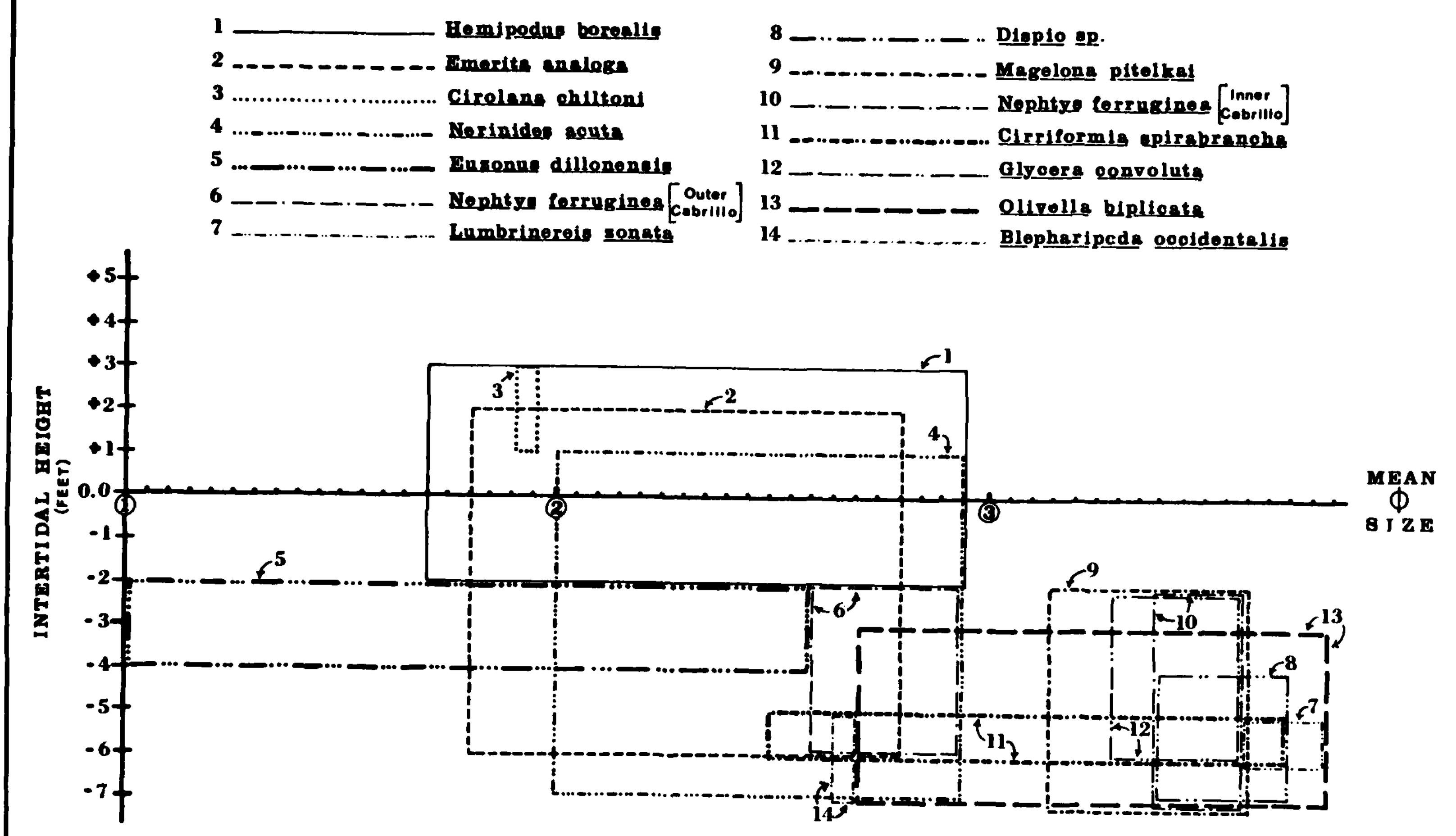
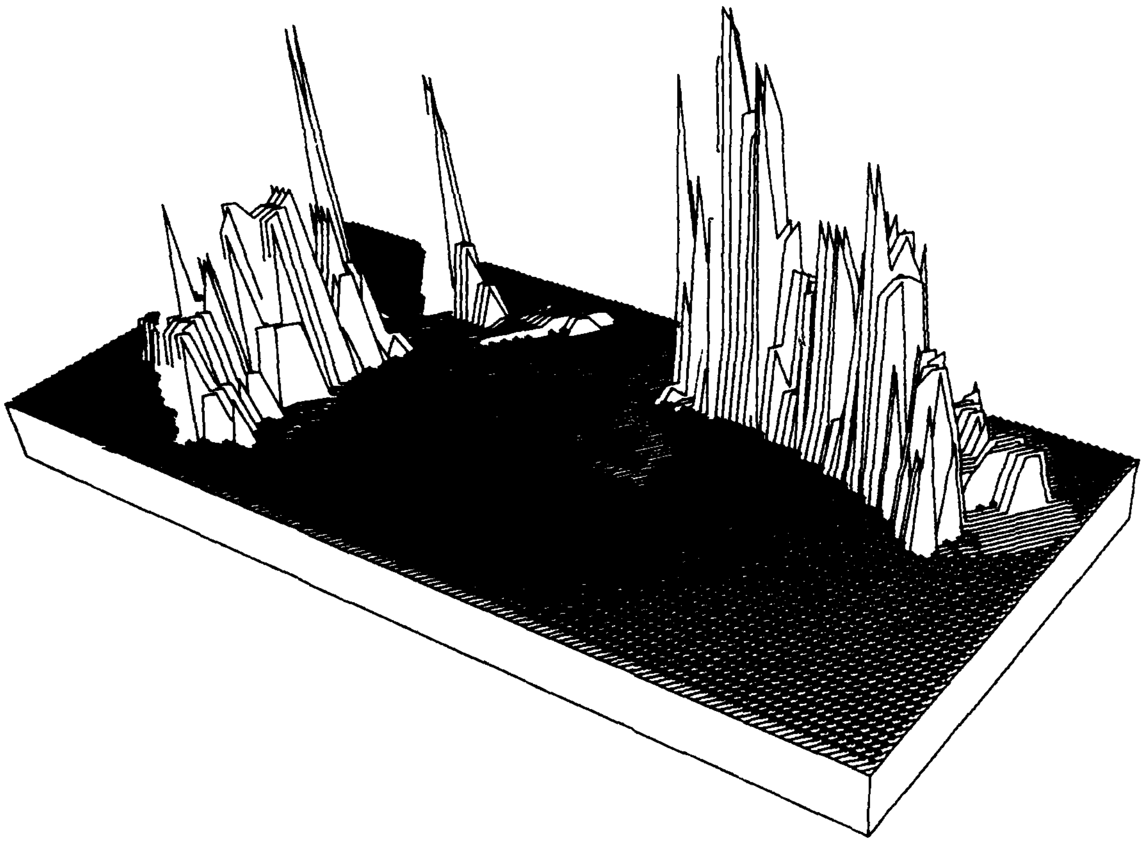


Figure 13.2. Species Distribution on an Intertidal Beach Transect.

Chapter 14

SOME SOCIO-ECONOMIC CHARACTERISTICS OF THE COAST ADJACENT TO THE LOS ANGELES - LONG BEACH HARBORS



Computer Stereogram of Population Densities of the Los Angeles-Long Beach Harbors Sector According to 1970 Census Data

Harbors Environmental Projects University of Southern California

CHAPTER 14

SOME SOCIO-ECONOMIC CHARACTERISTICS OF THE COAST ADJACENT TO THE LOS ANGELES - LONG BEACH HARBORS

By John W. McDonald
Department of Geography
University of Southern California

INTRODUCTION

Alterations to port facilities constitute changes in both marine and terrestrial environments that have potential impact on the human occupancy of the coastal area. It is the purpose of this report to depict the numbers and distribution of people in the adjacent coastal area and, by means of a few selected socio-economic characteristics, indicate the kinds of neighborhoods that might be affected as a consequence of future development.

To the drafters of the California Coastal Zone Conservation Act, the zone of critical concern was the strip of land immediately adjacent to the sea. Therefore, they incorporated into the Act language creating a permit area extending 1000 yards inland from mean high tide. This concept of a 1000-yard littoral has been preserved in the coastal zone legislation recently signed into law.

Maps and tables are presented to illustrate the current or recently existing characteristics of population and housing within the 1000-yard permit area. The present paper seeks to translate data from numbers into graphic representations of spatial relationships. Tabular presentations of data, while indispensable, do not have the visual impact of maps and require considerable time, talent, and tedium on the part of the user to detect patterns of differences and similarities or trends in coastal zone development. Therefore, a combination of tables, age-sex pyramids, and maps is used to provide information. The tables furnish actual values, while the graphics show aggregations of data by value ranges and spatial relationships.

This work is a result of research sponsored by NOAA office of Sea Grant, Department of Commerce, under Grant #04-3-158-145 to the USC Sea Grant Program. The material in this paper has been adapted from An Atlas of Coastal Zone Socio-Economic Characteristics: Los Angeles County (publication pending).

METHODS

The computer-generated maps in the present study are choroplethic in nature; that is to say, the data conform to areal statistical units. The program used in generating these maps, SYMAP, has the ability to convert raw census data, by means of calculations within the computer, into spatial patterns. Data values within statistical areas are represented by symbols comprised of single and overprinted computer line-printer typescript characters approximating a gradation of shading from light grey to black, usually representing from lowest to highest data values.

Interpretation of computer maps presents no problem even to users unaccustomed to this mode of data presentation. General patterns can be discerned by a casual examination of a map.

The maps of the study area have been divided into three sectors--Palos Verdes, Los Angeles (San Pedro)-Long Beach Harbors, and Long Beach. For each of these sectors six characteristics have been computer mapped: population density, housing density, percent of housing owner occupied, percent of housing renter occupied, mean value of owner-occupied housing, and average rent.

Symbolism on each of the 1000-yard permit area maps is designed to facilitate map-to-map comparison. For example, a given housing value has the same symbolism on all maps showing this characteristic. Below is shown a key taken from one of the maps which identifies the value symbolism appearing on that map. As can be seen, the entire range of values from zero to $50,000 or more has been divided into eight divisions, the first indicating no housing and, therefore, no value.

AVERAGE VALUE, OWNER OCCUPIED HOUSING

MINIMUM	0.0	20559.00	25000.00	30000.00	35000.00	40000.00	45000.00	50000.00
MAXIMUM	20559.00	25000.00	30000.00	35000.00	40000.00	45000.00	50000.00	59956.20
LEVEL	1	2	3	4	5	6	7	8

SYMBOLS

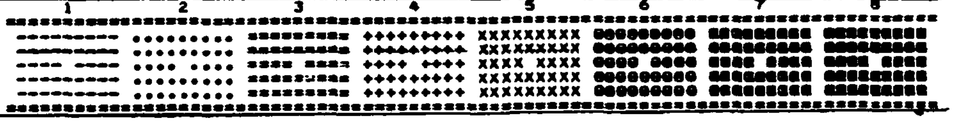


Figure 1 Map Symbolism, Housing Values

Because of the nature of the SYMAP program, the symbolism for any range of values includes all values from the lowest in that range of division up to but not including the highest. In column three of Figure 1, the symbol === represents a housing value from $25,000 to but not including $30,000. For column two the symbol ... represents the value range from the lowest value found in the sector ($16,272.50 in this case) up to but not including $25,000. The symbol --- indicates values below the lowest value, or zero. If a sector contains no housing in a given value range, the corresponding symbolism does not appear on that sector map; if the maximum value on a map falls in, for example, group six, symbolism for groups seven and eight does not appear on the map or in the histogram.

It will be noted that the following key uses the same symbolism to represent various levels of another important characteristic--housing density.

HOUSING DENSITY (UNITS PER SQUARE MILE)

MINIMUM	0.0	766.57	1280.00	2500.00	5000.00	10000.00	15000.00	20000.00
MAXIMUM	766.57	1280.00	2500.00	5000.00	10000.00	15000.00	20000.00	25903.23
LEVEL	1	2	3	4	5	6	7	8
SYMBOLS	---------	....	=========	+++++++++	XXXXXXXXX			

Figure 2 Map Symbolism, Housing Density

Again in this case, the symbol --- represents no housing, or a zero value, while the symbol ... represents the range of housing density from the lowest number in the sector to 1,279 housing units per square mile. The figure of 1,280 units per square mile used as a data division point is equal to the two-house-per-acre density used by some urban sociologists to represent a settled area(Duncan, et al., 1962; Van Arsdal and Schuerman, 1971).

The eight levels of symbolism are used on maps showing population density per square mile and average rent. As can be seen in the following example, population density data have been divided into eight levels: (1) zero, (2) lowest density to 2,500, (3) 2,500 to 5,000, (4) 5,000 to 10,000, (5) 10,000 to 15,000, (6) 15,000 to 20,000, (7) 20,000 to 30,000, and (8) 30,000 to highest density per square mile in a given sector. If the highest density were just less than 20,000 people per square mile, symbolism for only the first six levels would appear on the map.

POPULATION DENSITY (PER SQUARE MILE)								
MINIMUM	0.0	2200.40	2500.00	5000.00	10000.00	15000.00	20000.00	30000.00
MAXIMUM	2200.40	2500.00	5000.00	10000.00	15000.00	20000.00	30000.00	40750.21
LEVEL	1	2	3	4	5	6	7	8
SYMBOLS	---------	....	=========	+++++++++	XXXXXXXXX	OOOOOOOOO	[illegible]	[illegible]

Figure 3.Map Symbolism, Population Density

Average rent is divided into the following ranges: (1) below $75 per month, (2) $75 to $100 per month, (3) $100 to $125 per month, (4) $125 to $175 per month, (5) $175 to $225 per month, (6) $225 to $275 per month, (7) $275 to $300 per month, and (8) over $300 per month.

For the remaining two mapped characteristics, percent of housing owner occupied and percent of housing renter occupied, the data were divided into ten levels as shown below.

PERCENT OF HOUSING RENTER OCCUPIED										
MINIMUM	0.0	0.00	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
MAXIMUM	0.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	---------	....	[illegible]	OOOOOOOOO	+++++++++	XXXXXXXXX	[illegible]	[illegible]	[illegible]	[illegible]

Figure 4
Map Symbolism, Percent of Housing Renter Occupied

As in the preceding examples, the first division represents a zero value. The second division covers the range from the lowest reported value to 20 percent, while divisions three through nine represent increments of 10 percent. The tenth and last division includes 90 percent and the highest calculated value.

A legend, or key, to the symbolism and a histogram will be found on the page facing each map. The histogram indicates the number of census block groups on the map to be found in that value range.

The source of data for this section is the 1970 Census of Population and Housing. The 1970 Census remains the best

source for population information on small areas. Insofar as is known, no comprehensive and accurate estimates revising population data at the census tract and block group level have been made for the study area. A brief discussion of these "census geography" terms follows.

CENSUS TRACTS are the basic statistical divisions. The U. S. Bureau of the Census (1973) stated "Tract boundaries are determined by a local committee, subject to approval by the Bureau of the Census; they do not cross county lines. Tracts were designed initially to be relatively homogeneous with respect to population characteristics, economic status, and living conditions."

Although in theory census tracts contain 4,000 to 5,000 people, the population of census tracts can vary widely--from less than 1,000 to as many as 10,000.

BLOCK GROUPS are tabulation units newly created for the 1970 census within census tracts. A block group is a statistical unit formed by the aggregation of data from several contiguous "blocks" and, on the average, contain a population of about 1,000 persons.

BLOCKS as statistical units typically are synonymous with city blocks bounded on four sides by streets and normally contain about 100 persons. Blocks, however, may be irregular in shape and may be bounded on one or more sides by features other than streets.

The census block group was selected as the areal unit for mapping the study area. Among the reasons for this choice are (1) the block group is small enough in area that a great many of these areas fall completely within the 1000-yard area; (2) the block group is the smallest unit for which all census data are available; and (3) it permits a "finer grain" analysis of the study area than does the census tract.

RESULTS AND DISCUSSION

Population density, one of the most important single characteristics for judging the impact of development on an area, is presented graphically for each of the sectors by the accompanying maps. In a study prepared for Southern California Edison (1972), population density was divided into three categories: low--under 15,000 persons per square mile, medium--15,000 to 25,000 persons per square mile, and high--25,000 to 40,000 persons per square mile. From the popula-

tion density maps, it is seen that, by these criteria, the Palos Verdes sector, with its greatest population density only slightly over 6,000 persons per square mile, is an area of very low population density. The Los Angeles-Long Beach Harbors sector is of low to medium population density, and the greater part of the Long Beach sector is of high density.

Housing density is an important indicator of development and, in most instances, will reflect the same patterns as population density. Comparison of housing density maps with population density maps can reveal anomolous situations such as overcrowded living conditions or overbuilding of housing in terms of demand. In areas where the density patterns do not correspond, for example, when a census block group shows a high population density pattern but a low housing density pattern, one would expect to find more crowded housing conditions than if the opposite were true--population with a light density pattern and housing with a dark density pattern. With this situation one would expect less crowded housing conditions, or even a surplus of housing units.

In assessing the impact of any decision to institute change in an area, it can be assumed that renters are more mobile, have a smaller vested interest in the area, and are less likely to be organized than people living in their own homes. Housing values also must be considered, for a change in value will not only affect the tax base but also the political sensitivities of those who can afford expensive homes or apartments. Therefore, housing characteristics are illustrated by a series of maps which indicate by census block group, owner or renter occupancy, mean housing value, and average rent.

Considering the three 1000-yard sectors as communities, the population structure for each sector is illustrated by a computer generated age-sex pyramid, which graphically displays for an area the percent of the total population falling into sixteen age categories by sex. Further characteristics of the sector, or community, are found in the accompanying summary tables.

From these population pyramids, together with the maps and tables, one can form an impression of the socio-economic characteristics of a community (sector) as is illustrated in Table 4.

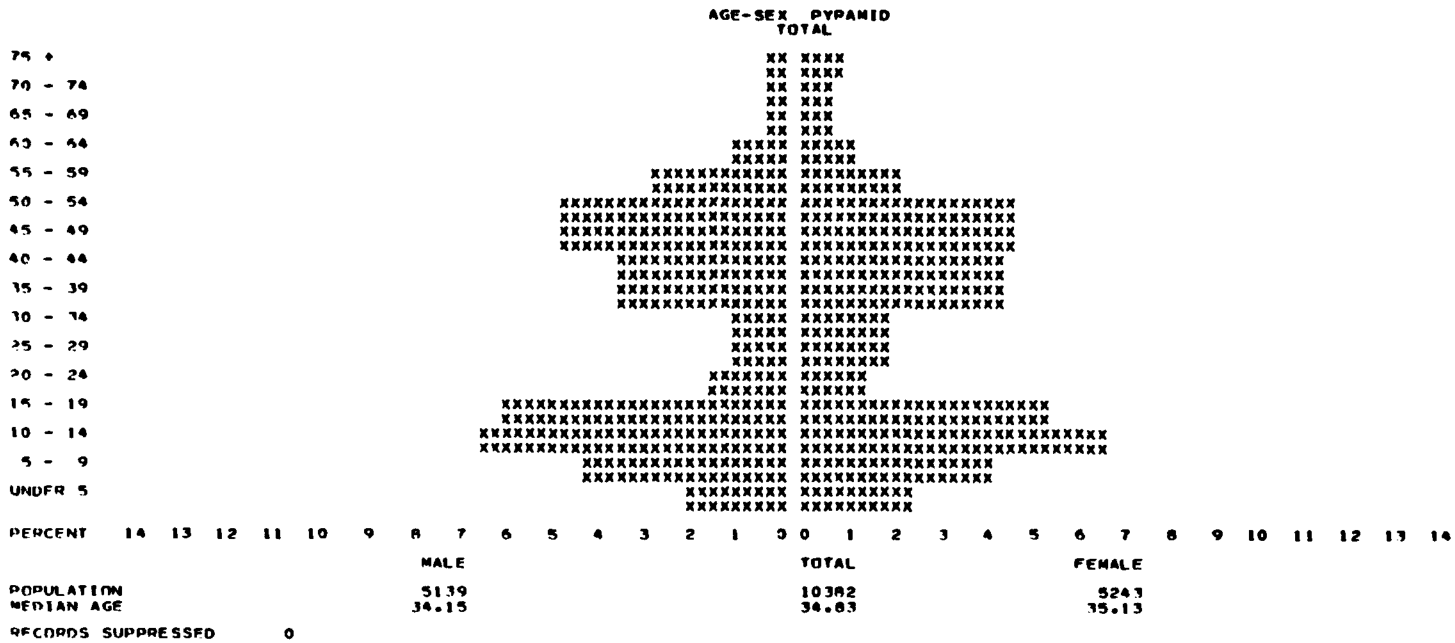


Figure 5 Palos Verdes Sector Age-Sex Pyramid

The Palos Verdes Sector is seen as a community of young couples (30 to 40 years of age) and their children. There are many teenagers but few young adults and fewer old people.

Table 1

POPULATION AND HOUSING SUMMARY: PALOS VERDES SECTOR

TOTAL

TOTAL POPULATION 10382

DATA ITEM	COUNT	PERCENT	RECORDS SUPPRESSED
WHITE POPULATION	10267	98.9	0
NEGRO POPULATION	15	0.1	0
INDIAN POPULATION	6	0.1	0
OTHER SPECIFIED RACES	80	0.8	0
REPORTED OTHER RACE	14	0.1	0
OWNER OCCUPIED DWELLING UNITS	2607	84.1	0
RENTER OCCUPIED DWELLING UNITS	407	13.1	0
VACANT DWELLING UNITS	86	2.8	0

TOTAL DWELLING UNITS 3100

DATA ITEM	COUNT	PERCENT	RECORDS SUPPRESSED
1-UNIT STRUCTURES	2613	84.3	0
2 OR MORE UNIT STRUCTURES	487	15.7	0
MOBILE HOMES	0	0.0	0
OVER CROWDED UNITS	32	1.0	0
UNITS LACKING PLUMBING FACILITIES	9	0.3	0
UNITS LACKING KITCHEN FACILITIES	3	0.1	0
POPULATION IN OVERCROWDED UNITS LACKING PLUMBING FACILITIES	0	0.0	0

VALUE OF OWNER OCCUPIED UNITS

	COUNT	PERCENT
LESS THAN 5000	0	0.0
5000- 9999	0	0.0
10000-14999	0	0.0
15000-19999	2	0.1
20000-24999	9	0.4
25000-34999	54	2.2
35000-49999	730	30.3
50000 +	1611	67.0
MEDIAN	50001.00	
RECORDS SUPPRESSED	0	

RENT OF RENTER OCCUPIED UNITS

	COUNT	PERCENT
LESS THAN 40	3	0.8
40-59	1	0.3
60-79	4	1.0
80-99	3	0.8
100-119	3	0.8
120-149	4	1.0
150-199	71	18.1
200-299	141	36.0
300 +	162	41.3
MEDIAN	275.80	
RECORDS SUPPRESSED	0	

TOTAL RECORDS 8

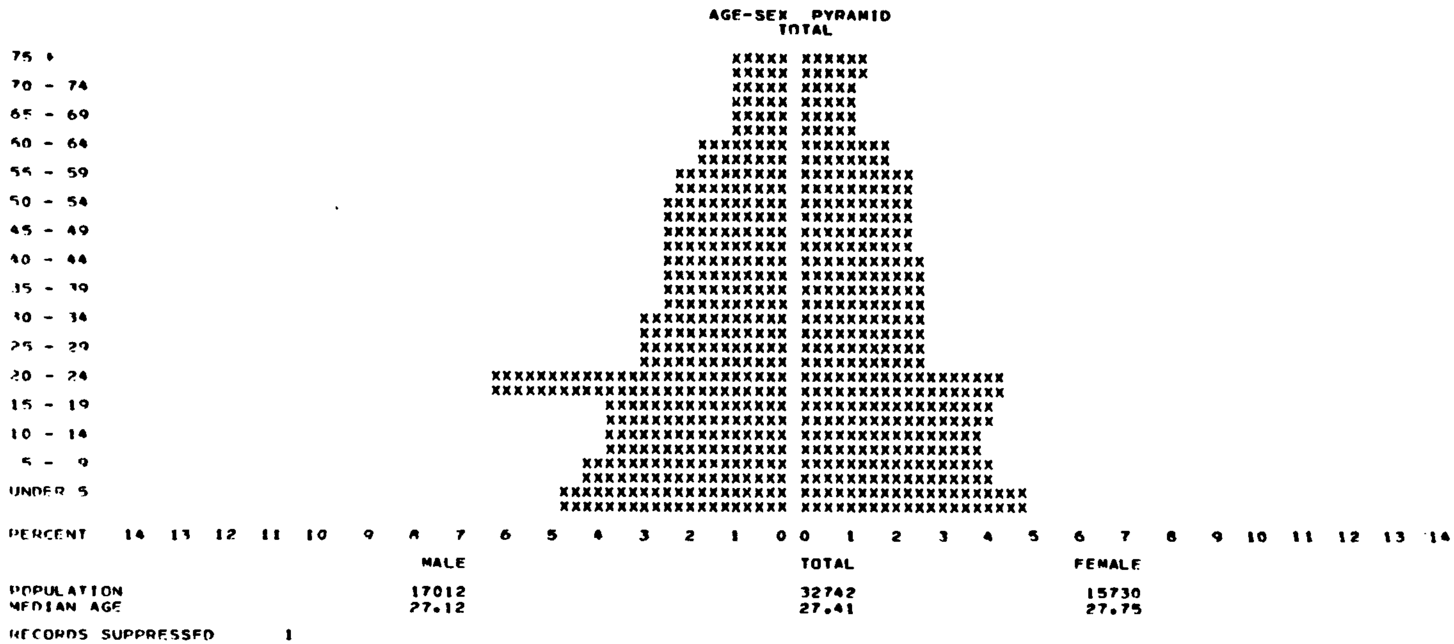


Figure 6 Los Angeles-Long Beach Harbors Age-Sex Pyramid

The population pyramid for the Los Angeles-Long Beach Harbors Sector reveals a community with a rather young median age and enough infants to provide for population growth.

Table 2

POPULATION AND HOUSING SUMMARY: LOS ANGELES-LONG BEACH HARBORS SECTOR

TOTAL

TOTAL POPULATION 32746

DATA ITEM	COUNT	PERCENT	RECORDS SUPPRESSED
WHITE POPULATION	27699	84.6	1
NEGRO POPULATION	2248	6.9	1
INDIAN POPULATION	141	0.4	1
OTHER SPECIFIED RACES	2242	6.8	1
REPORTED OTHER RACE	412	1.3	1
OWNER OCCUPIED DWELLING UNITS	4069	34.3	2
RENTER OCCUPIED DWELLING UNITS	7087	59.8	2
VACANT DWELLING UNITS	701	5.9	2

TOTAL DWELLING UNITS 11860

DATA ITEM	COUNT	PERCENT	RECORDS SUPPRESSED
1-UNIT STRUCTURES	6098	51.4	2
2 OR MORE UNIT STRUCTURES	5599	47.2	2
MOBILE HOMES	160	1.3	2
OVER CROWDED UNITS	1428	12.0	2
UNITS LACKING PLUMBING FACILITIES	577	4.9	2
UNITS LACKING KITCHEN FACILITIES	536	4.5	2
POPULATION IN OVERCROWDED UNITS LACKING PLUMBING FACILITIES	159	0.0	2

VALUE OF OWNER OCCUPIED UNITS

	COUNT	PERCENT
LESS THAN 5000	9	0.3
5000- 9999	145	4.1
10000-14999	454	12.9
15000-19999	832	23.6
20000-24999	756	21.5
25000-34999	793	22.5
35000-49999	415	11.8
50000 +	117	3.3
MEDIAN	22115.00	
RECORDS SUPPRESSED	5	

RENT OF RENTER OCCUPIED UNITS

	COUNT	PERCENT
LESS THAN 40	314	4.6
40-59	1189	17.3
60-79	1822	26.5
80-99	1227	17.9
100-119	799	11.6
120-149	821	11.9
150-199	538	7.8
200-299	136	2.0
300 +	25	0.4
MEDIAN	81.78	
RECORDS SUPPRESSED	3	

TOTAL RECORDS 36

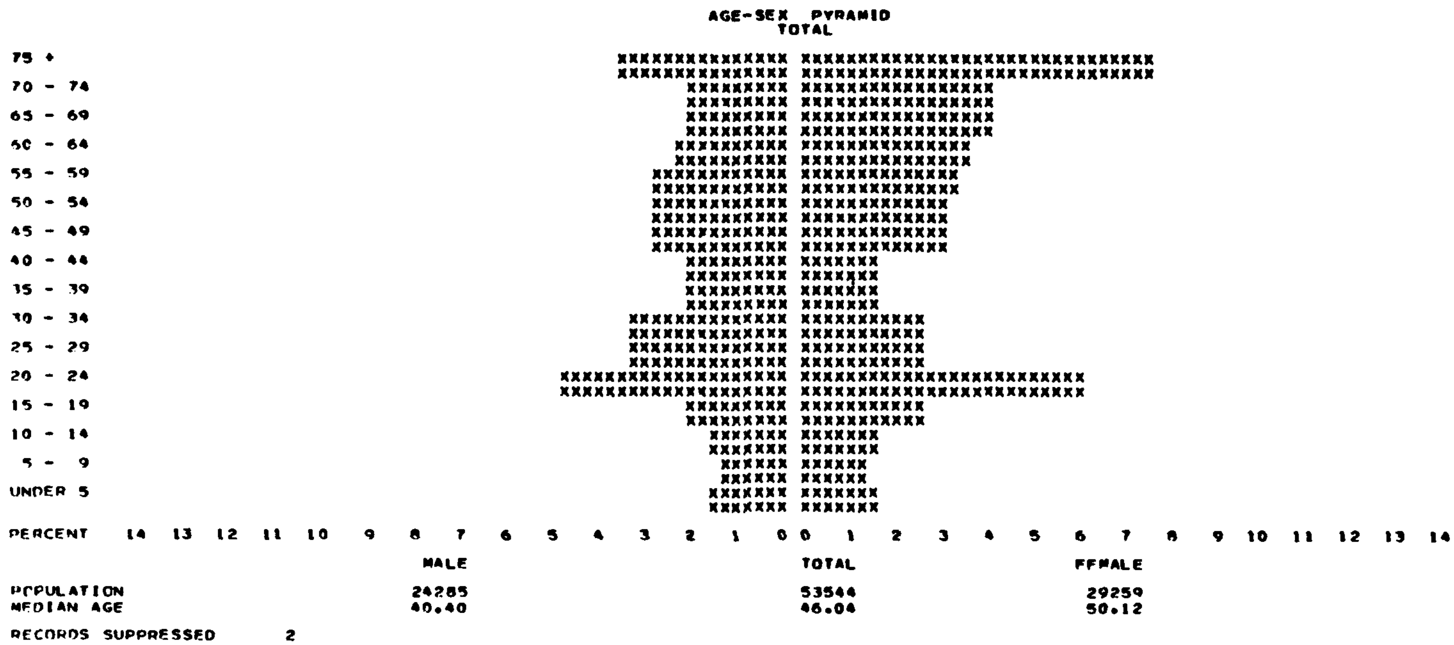


Figure 7 Long Beach Sector Age-Sex Pyramid

The Long Beach Sector pyramid indicates an aging population with many fewer infants than necessary to sustain a population without immigration. Note the large number of elderly ladies.

Table 3

POPULATION AND HOUSING SUMMARY: LONG BEACH SECTOR

TOTAL

TOTAL POPULATION 53549

DATA ITEM	COUNT	PERCENT	RECORDS SUPPRESSED
WHITE POPULATICN	52644	98.3	2
NEGRO POPULATICN	170	0.3	2
INDIAN POPULATION	145	0.3	2
OTHER SPECIFIED RACES	462	0.9	2
REPORTED OTHER RACE	123	0.2	2
OWNER OCCUPIED DWELLING UNITS	9639	31.1	2
RENTER OCCUPIED DWELLING UNITS	19283	62.3	2
VACANT DWELLING UNITS	2035	6.6	2

TOTAL DWELLING UNITS 30971

DATA ITEM	COUNT	PERCENT	RECORDS SUPPRESSED
1-UNIT STRUCTURES	8666	28.0	2
2 OR MORE UNIT STRUCTURES	22014	71.1	2
MOBILE HCMES	277	0.9	2
OVER CROWDED UNITS	538	1.7	2
UNITS LACKING PLUMBING FACILITIES	728	2.4	2
UNITS LACKING KITCHEN FACILITIES	856	2.8	2
POPULATION IN OVERCROWDED UNITS LACKING PLUMBING FACILITIES	89	0.0	2

VALUE OF OWNER OCCUPIED UNITS

	COUNT	PERCENT
LESS THAN 5000	13	0.2
5000- 9999	68	1.3
10000-14999	145	2.7
15000-19999	395	7.3
20000-24999	790	14.6
25000-34999	1709	31.5
35000-49999	1411	26.0
50000 +	891	16.4
MEDIAN	32600.00	
RECORDS SUPPRESSED	12	

RENT OF RENTER OCCUPIED UNITS

	COUNT	PERCENT
LESS THAN 40	205	1.1
40-59	1187	6.3
60-79	4468	23.6
80-99	3621	19.2
100-119	2361	12.5
120-149	3169	16.8
150-199	2448	13.0
200-299	1145	6.1
300 +	289	1.5
MEDIAN	99.80	
RECORDS SUPPRESSED	2	

TOTAL RECORDS 60

Table 4

SELECTED SOCIO-ECONOMIC CHARACTERISTICS

	Palos Verdes	Los Angeles-Long Beach Harbors	Long Beach
Population			
Total	12,082	28,691	54,850
Percent White	98.9%	84.6%	98.3%
Median Age (years)	34.8	27.4	46.0
Housing			
Percent Renter Occupied	15.9%	59.8%	62.0%
Percent Multiple Units	15.7%	48.6%	71.9%
Average Rent	$275	$81	$99
Median Value Owner Occ.	$50,000	$22,115	$32,600

A close examination of block group data will reveal that, except for the Palos Verdes sector with its remarkable homogeneity, there is a wealth of diversity within these communities. Many neighborhoods which reflect wide ranging patterns of life styles can be identified and located. For example, on the map depicting the population density of the Los Angeles-Long Beach Harbors (Page 59) we may look at Block Group one of Census Tract 2949 (found near the edge of the map, north of West Basin) and find that this block group has a population density of between 15,000 and 20,000 persons per square mile. The age-sex pyramid (Figure 8) reveals a young population with a median age of 23.48 years. This example

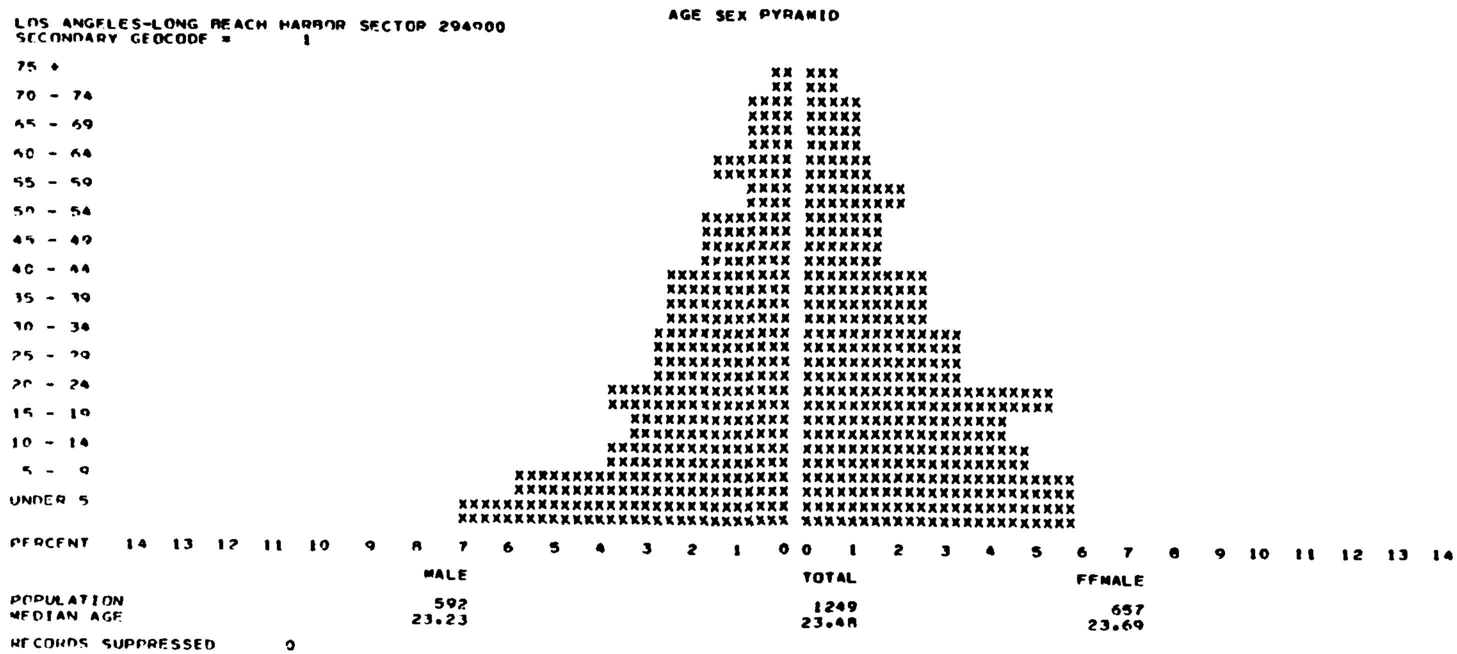


Figure 8

AGE-SEX PYRAMID FOR BLOCK GROUP 1, CENSUS TRACT 2949

Table 5

LOS ANGELES-LONG BEACH HARBOR SECTOR 294900
SECONDARY GEOCODE = 1

TOTAL POPULATION 1249

DATA ITEM	COUNT	PERCENT	RECORDS SUPPRESSED
WHITE POPULATION	825	66.1	0
NEGRO POPULATION	55	4.4	0
INDIAN POPULATION	8	0.6	0
OTHER SPECIFIED RACES	276	22.1	0
REPORTED OTHER RACE	85	6.8	0
OWNER OCCUPIED DWELLING UNITS	141	37.7	0
RENTER OCCUPIED DWELLING UNITS	225	60.2	0
VACANT DWELLING UNITS	8	2.1	0

TOTAL DWELLING UNITS 374

DATA ITEM	COUNT	PERCENT	RECORDS SUPPRESSED
1-UNIT STRUCTURES	257	68.7	0
2 OR MORE UNIT STRUCTURES	117	31.3	0
MOBILE HOMES	0	0.0	0
OVER CROWDED UNITS	82	21.9	0
UNITS LACKING PLUMBING FACILITIES	0	0.0	0
UNITS LACKING KITCHEN FACILITIES	0	0.0	0
POPULATION IN OVERCROWDED UNITS LACKING PLUMBING FACILITIES	0	0.0	0

VALUE OF OWNER OCCUPIED UNITS

	COUNT	PERCENT
LESS THAN 5000	0	0.0
5000- 9999	2	1.5
10000-14999	17	12.5
15000-19999	73	53.7
20000-24999	33	24.3
25000-34999	11	8.1
35000-49999	0	0.0
50000 +	0	0.0
MEDIAN	18355.00	
RECORDS SUPPRESSED	0	

RENT OF RENTER OCCUPIED UNITS

	COUNT	PERCENT
LESS THAN 40	10	4.6
40-59	40	18.3
60-79	47	21.6
80-99	43	19.7
100-119	33	15.1
120-149	29	13.3
150-199	16	7.3
200-299	0	0.0
300 +	0	0.0
MEDIAN	85.58	
RECORDS SUPPRESSED	0	

TOTAL RECORDS 1

POPULATION AND HOUSING SUMMARY: BLOCK GROUP 1 of CENSUS TRACT 2949

illustrates a normal, or growing, population with a broad base, indicating large numbers of children, and a small apex, indicating few old people. Table 5 reveals racial diversity in this block group. Only 66 percent of the population is Caucasion, while 22 percent is made up of "other specified races," in this case mostly Filipino.

Another example of diversity in population structure is to be found in Block Group One of Census Tract 5774 of the Long Beach Sector (Figure 9). The population pyramid for this area, with its nearly straight sides, illustrates an approximation of zero population growth; a stable situation in which fertility is just sufficient for replacement.

The third example is illustrated by an inverted pyramid showing a condition sometimes found in older neighborhoods (Figure 10). Such a neighborhood faces the same future as its inhabitants. This pyramid illustrates the extreme condition that prevailed in 1970 in Block Group Two of Census Tract 5759 of downtown Long Beach. At that time the inhabitants of this neighborhood had a median age of 71.48 years. A recent field check of the area revealed that, while many elderly people still live there, many old houses and apartments were standing empty and others were being razed. The neighborhood was in the process of being "recycled."

Examples 1 and 3 both represent potential problem areas for the larger community in that both are comprised largely of non-productive dependent members of society, one needing schools and playgrounds and the other facilities for the aged and indigent.

This study discloses a variety of life styles in the coastal zone as a whole. Even at the level of the census tract, which according to the U. S. Bureau of the Census (1961) was "designed to be relatively uniform with respect to population characteristics, economic status, and living conditions. . .", great variety within a tract itself is disclosed by the block group maps. This ability to recognize the existence of communities by socio-economic characteristics rather than by political boundaries can be useful in planning.

One of the basic policy proposals of the South Coast Regional Commission (1974) was to "identify distinctive coastal neighborhoods and regulate development to ensure their physical and social well-being." And one of the planning goals was "to recognize and maintain the diversity of

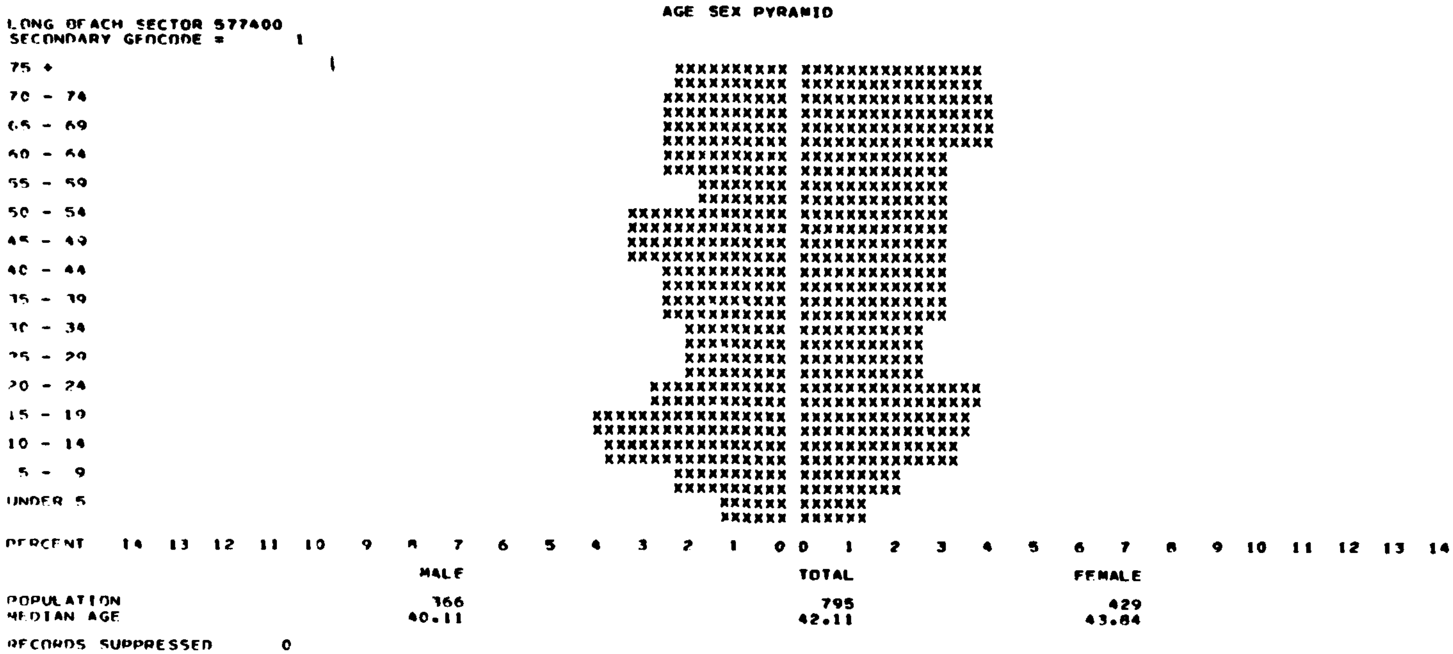


Figure 9

AGE-SEX PYRAMID FOR BLOCK GROUP 1, CENSUS TRACT 5774

Table 6

LONG BEACH SECTOR 5774C0
SECONDARY GEOCODE = 1

TOTAL POPULATION 795

DATA ITEM	COUNT	PERCENT	RECORDS SUPPRESSED
WHITE POPULATION	778	97.9	0
NEGRO POPULATION	1	0.1	0
INDIAN POPULATION	1	0.1	0
OTHER SPECIFIED RACES	15	1.9	0
REPORTED OTHER RACE	0	0.0	0
OWNER OCCUPIED DWELLING UNITS	193	54.5	0
RENTER OCCUPIED DWELLING UNITS	147	41.5	0
VACANT DWELLING UNITS	14	4.0	0

VALUE OF OWNER OCCUPIED UNITS

	COUNT	PERCENT
LESS THAN 5000	0	0.0
5000- 9999	1	0.6
10000-14999	1	0.6
15000-19999	6	3.9
20000-24999	21	13.6
25000-34999	44	28.6
35000-49999	43	27.9
50000 +	38	24.7
MEDIAN	36395.00	
RECORDS SUPPRESSED	0	

TOTAL DWELLING UNITS 354

DATA ITEM	COUNT	PERCENT	RECORDS SUPPRESSED
1-UNIT STRUCTURES	213	60.2	0
2 OR MORE UNIT STRUCTURES	141	39.8	0
MOBILE HOMES	0	0.0	0
OVER CROWDED UNITS	6	1.7	0
UNITS LACKING PLUMBING FACILITIES	1	0.3	0
UNITS LACKING KITCHEN FACILITIES	1	0.3	0
POPULATION IN OVERCROWDED UNITS LACKING PLUMBING FACILITIES	0	0.0	0

RENT OF RENTER OCCUPIED UNITS

	COUNT	PERCENT
LESS THAN 40	1	0.7
40-59	1	0.7
60-79	11	7.7
80-99	12	8.4
100-119	17	11.9
120-149	30	21.0
150-199	53	37.1
200-299	18	12.6
300 +	0	0.0
MEDIAN	148.98	
RECORDS SUPPRESSED	0	

TOTAL RECORDS 1

POPULATION AND HOUSING SUMMARY: BLOCK GROUP 1 of CENSUS TRACT 5774

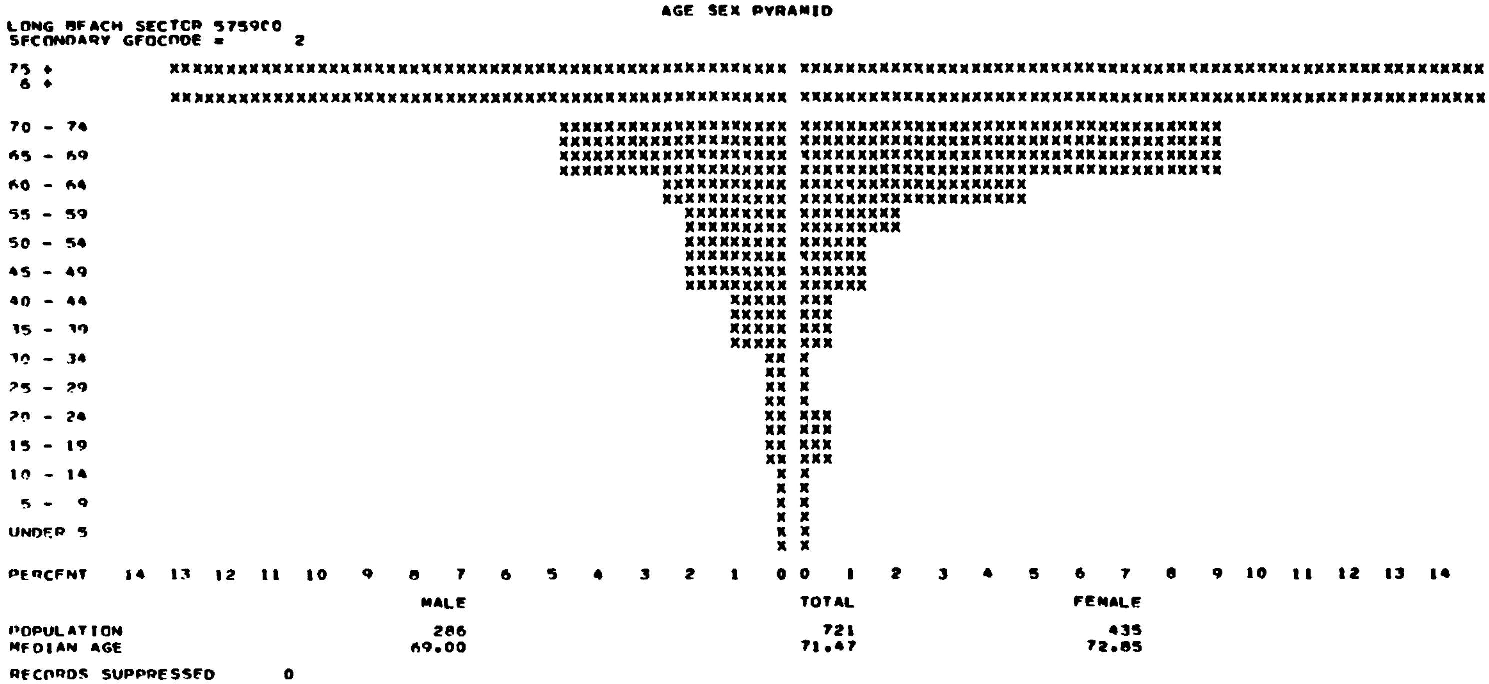


Figure 10

AGE-SEX PYRAMID FOR BLOCK GROUP 2, CENSUS TRACT 5959

Table 7

LONG REACH SECTOR 575900
SECONDARY GEOCODE = 2

TOTAL POPULATION 721

DATA ITEM	COUNT	PERCENT	RECORDS SUPPRESSED
WHITE POPULATION	710	98.5	0
NEGRO POPULATION	1	0.1	0
INDIAN POPULATION	5	0.7	0
OTHER SPECIFIED RACES	5	0.7	0
REPORTED OTHER RACE	0	0.0	0
OWNER OCCUPIED DWELLING UNITS	156	23.5	0
RENTER OCCUPIED DWELLING UNITS	431	64.9	0
VACANT DWELLING UNITS	77	11.6	0

TOTAL DWELLING UNITS 664

DATA ITEM	COUNT	PERCENT	RECORDS SUPPRESSED
1-UNIT STRUCTURES	29	4.4	0
2 OR MORE UNIT STRUCTURES	632	95.2	0
MOBILE HOMES	3	0.5	0
OVER CROWDED UNITS	20	3.0	0
UNITS LACKING PLUMBING FACILITIES	91	13.7	0
UNITS LACKING KITCHEN FACILITIES	88	13.3	0
POPULATION IN OVERCROWDED UNITS LACKING PLUMBING FACILITIES	20	2.8	0

VALUE OF OWNER OCCUPIED UNITS

	COUNT	PERCENT
LESS THAN 5000	0	0.0
5000- 9999	2	40.0
10000-14999	0	0.0
15000-19999	0	0.0
20000-24999	0	0.0
25000-34999	0	0.0
35000-49999	0	0.0
50000 +	3	60.0
MEDIAN	10000.00	
RECORDS SUPPRESSED	0	

RENT OF RENTER OCCUPIED UNITS

	COUNT	PERCENT
LESS THAN 40	3	0.7
40-59	118	27.8
60-79	250	59.0
80-99	47	11.1
100-119	5	1.2
120-149	1	0.2
150-199	0	0.0
200-299	0	0.0
300 +	0	0.0
MEDIAN	67.28	
RECORDS SUPPRESSED	0	

TOTAL RECORDS 1

POPULATION AND HOUSING SUMMARY: BLOCK GROUP 2 of CENSUS TRACT 5759

life styles and opportunities for all income levels and social groups, both residing and visiting in the Coastal Zone." Although the study is based on data gathered in 1970, the data's continued usefulness in identifying communities has been verified by several field inspections. Neighborhoods tend to change slowly unless bulldozed.

This work serves to demonstrate the usefulness of computer generated graphics as tools for "a society to find out about itself," by reducing huge amounts of Census data into manageable and recognizable patterns. It is then possible to assess the impact of proposed development in terms of numbers of people affected and housing values.

Population and housing density, useful as they are, give few clues to the non-residential use of areas. Unfortunately, the available data did not permit production of maps and tables to indicate intensity of use by commerce and industry. Another use of the coastal zone that cannot be evaluated with census data is that concerning non-residents, people seeking shore-related recreation. On any hot summer weekend, the 1000-yard coastal permit area may have a non-resident population of thousands.

LITERATURE CITED

Duncan, Beverly, Georges Sabogh, and Maurice Van Arsdol, 1962. Patterns of city growth. American Journal of Sociology, vol. 67.

South Coast Regional Commission, California Coastal Zone Conservation Commission, The intensity of development element for the south coast region (preliminary version), 1974. pp. iii, 51.

Southern California Edison Co., Southern division land use study and forecast of load growth, 1970-1990, 1972.

U. S. Bureau of the Census, 1961. U. S. census of population and housing: 1960, census tracts, final report phc(1)-82. p. 1.

U. S. Bureau of the Census, 1973. 1970 census geography: concepts, products, and programs. Data Access Descriptions No. 33.

TABLE OF FIGURES

*Computer map legends are placed before their respective computer maps.

L O S   A N G E L E S   C O U N T Y   C O A S T A L   Z O N E

1000-YARD PERMIT AREA, HOUSING UNITS AT ADDRESS*

PALOS VERDES SECTOR

CENSUS TRACT	BLOCK GROUP	PERCENT OF AREA WITHIN PERMIT AREA	TOTAL HOUSING UNITS	ONE UNIT	TWO-FOUR UNITS	FIVE-NINE UNITS	TEN-OR-MORE UNITS	MOBILE HOMES
670101	3	20	660	557	3	20	46	1
670301	4	73	583	521	12	10	14	0
670302	1	4	418	418	0	0	0	0
670302	2	75	284	284	0	0	0	0
670302	3	22	452	389	4	14	44	0
670302	4	100	301	301	0	0	0	0
670302	5	100	464	455	1	8	0	0
670401	3	33	1225	1104	17	38	66	0
670600	1	72	571	565	2	0	1	0
670600	2	52	445	99	17	9	289	0
670600	9	51	838	832	3	0	0	0

SOURCE: U.S. CENSUS, 1970
*NOTE: DATA ARE FOR COMPLETE BLOCK GROUPS RATHER THAN LIMITED TO 1000-YARD BOUNCARY

Table 8

L O S   A N G E L E S   C O U N T Y   C O A S T A L   Z O N E

AREAS AND POPULATION OF CENSUS BLOCK GROUPS WITHIN 1000-YARD PERMIT AREA

PALOS VERDES SECTOR

CENSUS TRACT	BLOCK GROUP	AREA SQ MI	AREA ACRES	PERCENT OF TOTAL AREA OF BLK GRP	ESTIMATED PERCENT OF TOTAL POPULATION OF BLK GRP*
670101	3	0.14	89.18	20.	39.
670301	4	0.52	332.34	73.	85.
670302	1	0.03	21.16	4.	4.
670302	2	0.48	307.07	75.	80.
670302	3	0.20	124.89	22.	60.
670302	4	0.54	344.06	100.	100.
670302	5	0.39	250.95	100.	100.
670401	3	0.69	441.65	33.	40.
670600	1	0.34	219.21	72.	47.
670600	2	0.13	83.31	52.	82.
670600	9	2.73	1749.86	51.	41.

*PERCENT OF POPULATION IN 1000-YARD AREA ESTIMATED BY PHILLIP SYMONDS, CENTER FOR URBAN AFFAIRS,USC

Table 9

L O S   A N G E L E S   C O U N T Y   C O A S T A L   Z O N E

1000-YARD PERMIT AREA

PALOS VERDES SECTOR

CENSUS TRACT	BLOCK GROUP	POPULATION	POPULATION DENSITY/ SQ MI	NUMBER OF HOUSING UNITS	HOUSING DENSITY/ SQ MI	HOUSING DENSITY/ ACRE	OWNER OCCUPIED HOUSING MEAN VALUE	OWNER OCCUPIED HOUSING PERCENT OF TOTAL HOUSING	RENTER OCCUPIED HOUSING AVERAGE RENT	RENTER OCCUPIED HOUSING PERCENT OF TOTAL HOUSING
670301	3	792	5689	257	1847	2.89	51412.40	77.	244.51	22.
670301	4	1526	2939	495	954	1.49	58786.21	84.	197.75	14.
670302	1	63	1925	16	505	0.79	58181.44	96.	298.38	4.
670302	2	804	1677	227	473	0.74	53270.11	94.	299.94	6.
670302	3	986	5055	271	1389	2.17	54241.07	81.	233.36	18.
670302	4	1161	2171	301	553	0.86	55540.78	94.	349.94	6.
670302	5	1717	4378	464	1183	1.85	53244.69	93.	290.12	7.
670401	3	1874	2716	489	710	1.11	52410.21	87.	274.38	13.
670600	1	556	2792	268	783	1.22	49698.85	94.	291.93	5.
670600	2	822	6318	364	2803	4.38	54559.38	58.	284.47	40.
670600	9	1361	497	343	125	0.20	51436.92	91.	250.07	7.

SOURCE: U.S. CENSUS, 1970

Table 10

POPULATION AND HOUSING CHARACTERISTICS

L O S   A N G E L E S   C O U N T Y   C O A S T A L   Z O N E

1000-YARD PERMIT AREA, HOUSING UNITS AT ADDRESS*

LOS ANGELES-LONG BEACH HARBOR SECTOR

CENSUS TRACT	BLOCK GROUP	PERCENT OF AREA WITHIN PERMIT AREA	TOTAL HOUSING UNITS	ONE UNIT	TWO-FOUR UNITS	FIVE-NINE UNITS	TEN-OR-MORE UNITS	MOBILE HOMES
294700	3	100	213	10	3	0	59	140
294700	5	79	125	69	5	17	29	1
294700	6	98	209	98	15	12	64	2
294700	7	100	13	10	2	0	0	0
294800	2	51	222	119	17	35	31	0
294800	3	71	418	233	44	20	21	0
294900	1	42	374	257	37	27	10	0
294900	2	84	381	102	47	29	2	0
294900	3	100	56	18	0	1	31	0
295100	2	15	665	665	0	0	0	0
295100	9	44	227	133	2	0	0	0
296200	1	100	318	164	38	5	45	0
296200	2	100	101	32	5	5	20	0
296200	3	100	391	198	26	9	10	0
296200	4	100	530	124	25	11	68	1
296200	5	100	270	76	8	14	101	0
296300	1	49	347	89	4	37	172	0
296300	2	6	601	157	81	1	0	0
296500	1	92	398	260	24	23	26	0
296500	2	17	391	307	24	0	0	1
296500	3	80	267	226	19	8	1	0
296900	2	10	532	259	41	41	22	0
296900	3	11	567	294	56	15	8	0
297100	1	100	69	14	0	1	29	7
297100	2	100	547	199	23	17	136	0
297100	3	100	620	289	46	17	92	0
297100	4	100	499	293	41	29	35	0
297100	5	100	524	238	44	2	67	0
297200	1	55	639	334	133	30	13	0
297200	2	47	409	178	68	30	27	0
297300	2	12	283	229	42	0	0	0
297300	3	98	265	250	0	0	0	0
297400	2	21	165	165	0	0	0	0
297400	3	100	648	551	0	0	97	0
297500	1	85	514	229	8	28	20	1
297500	2	100	247	243	2	0	0	0
297500	3	100	400	370	0	7	0	0
297600	1	100	456	78	12	18	196	9
297600	2	100	384	162	21	69	31	0
297600	3	100	535	262	40	49	18	0
297600	4	100	518	340	55	22	41	0

SOURCE: U.S. CENSUS, 1970
*NOTE: DATA ARE FOR COMPLETE BLOCK GROUPS RATHER THAN LIMITED TO 1000-YARD BOUNDARY

Table 11

L O S   A N G E L E S   C O U N T Y   C O A S T A L   Z O N E

AREAS AND POPULATION OF CENSUS BLOCK GROUPS WITHIN 1000-YARD PERMIT AREA

LOS ANGELES-LONG BEACH HARBOR SECTOR

CENSUS TRACT	BLOCK GROUP	AREA SQ MI	AREA ACRES	PERCENT OF TOTAL AREA OF BLK GRP	ESTIMATED PERCENT OF TOTAL POPULATION OF BLK GRP*
294700	3	0.40	256.09	100.	100.
294700	5	0.17	110.78	79.	70.
294700	6	0.34	220.09	98.	99.
294700	7	0.02	14.25	100.	100.
294800	2	0.09	58.77	51.	58.
294800	3	0.09	59.36	71.	49.
294900	1	0.04	22.92	42.	49.
294900	2	0.06	39.96	84.	100.
294900	3	0.78	498.66	100.	100.
295100	2	0.05	33.20	15.	2.
295100	9	0.92	591.22	44.	14.
296200	1	0.35	223.47	100.	100.
296200	2	0.11	71.55	100.	100.
296200	3	0.08	48.34	100.	100.
296200	4	0.15	98.73	100.	100.
296200	5	0.10	64.94	100.	100.
296300	1	0.10	64.65	49.	100.
296300	2	0.01	8.23	6.	13.
296500	1	0.13	81.10	92.	85.
296500	2	0.02	13.08	17.	19.
296500	3	0.09	58.33	80.	62.
296500	2	0.01	7.64	10.	10.
296900	3	0.02	11.90	11.	22.
297100	1	0.40	257.12	100.	100.
297100	2	0.08	49.37	100.	100.
297100	3	0.08	53.48	100.	100.
297100	4	0.08	48.93	100.	100.
297100	5	0.16	103.43	100.	100.
297200	1	0.05	31.74	55.	59.
297200	2	0.03	19.39	47.	51.
297300	2	0.01	4.70	12.	17.
297300	3	0.36	231.11	98.	96.
297400	2	0.03	19.69	21.	15.
297400	3	0.44	279.30	100.	100.
297500	1	0.33	209.81	85.	33.
297500	2	0.09	60.24	100.	100.
297500	3	0.15	97.56	100.	100.
297600	1	0.16	101.52	100.	100.
297600	2	0.09	56.57	100.	100.
297600	3	0.11	70.67	100.	100.
297600	4	0.08	52.30	100.	100.
294600	1	0.03	18.24	14.	NO POPULATION
294700	2	0.40	256.83	64.	NO POPULATION
294700	4	0.24	157.18	24.	NO POPULATION
296100	1	0.56	357.88	100.	NO POPULATION
296100	2	0.65	416.79	100.	NO POPULATION
296100	9	0.44	281.34	100.	NO POPULATION
297600	5	0.25	163.07	91.	NO POPULATION
575500	3	0.07	47.16	69.	NO POPULATION
575600	1	0.15	95.48	100.	NO POPULATION
575600	2	0.98	628.99	100.	NO POPULATION
575600	3	0.65	416.83	100.	NO POPULATION
575600	6	0.04	25.15	100.	NO POPULATION
575600	9	0.38	245.50	100.	NO POPULATION
575700	9	0.42	265.36	100.	NO POPULATION

*PERCENT OF POPULATION IN 1000-YARD AREA ESTIMATED BY PHILLIP SYMONDS, CENTER FOR URBAN AFFAIRS,USC

Table 12

LOS ANGELES COUNTY COASTAL ZONE

1000-YARD PERMIT AREA

LOS ANGELES-LONG BEACH HARBOR SECTOR

CENSUS TRACT	BLOCK GROUP	POPULATION	POPULATION DENSITY/ SQ MI	NUMBER OF HOUSING UNITS	HOUSING DENSITY/ SQ MI	HOUSING DENSITY/ ACRE	OWNER OCCUPIED HOUSING MEAN VALUE	OWNER OCCUPIED HOUSING PERCENT OF TOTAL HOUSING	RENTER OCCUPIED HOUSING AVERAGE RENT	RENTER OCCUPIED HOUSING PERCENT OF TOTAL HOUSING
294700	3	339	847	213	532	0.83	0.0	63.	49.68	37.
294700	5	235	1358	87	505	0.79	15720.59	15.	70.81	83.
294700	6	496	1445	206	601	0.94	15068.18	18.	57.46	81.
294700	7	39	1347	13	583	0.91	27666.66	54.	117.33	46.
294800	2	363	3960	128	1402	2.19	20382.35	32.	89.34	65.
294800	3	690	7449	204	2208	3.45	19075.82	34.	92.97	65.
294900	1	612	17089	183	5117	8.00	19368.52	38.	86.74	61.
294900	2	1422	22772	381	6101	9.53	18697.91	14.	65.17	85.
294900	3	105	134	56	71	0.11	23916.66	16.	69.09	79.
295100	2	55	1077	13	256	0.40	30909.05	93.	204.07	7.
295100	9	152	165	31	34	0.05	23745.10	25.	99.20	75.
296200	1	831	2379	318	910	1.42	17381.58	29.	75.78	70.
296200	2	335	2996	101	903	1.41	21500.00	11.	61.34	88.
296200	3	1173	15530	391	5176	8.09	17016.02	24.	67.31	75.
296200	4	1502	9736	530	3435	5.37	19455.36	7.	61.63	92.
296200	5	510	5026	270	2660	4.16	16654.76	13.	56.30	87.
296300	1	702	6549	347	3435	5.37	27556.03	19.	128.91	69.
296300	2	363	28313	78	6077	9.50	30370.13	14.	99.74	86.
296500	1	955	7539	338	2669	4.17	16703.36	39.	74.38	56.
296500	2	250	12265	74	3636	5.68	15500.00	43.	76.67	57.
296500	3	520	5714	165	1816	2.84	16627.55	58.	87.07	42.
296900	2	123	10370	53	4456	6.96	21302.78	22.	88.17	77.
296900	3	312	16823	124	6708	10.48	21791.66	33.	97.71	67.
297100	1	90	224	69	171	0.27	0.0	13.	54.47	86.
297100	2	1437	18629	547	7091	11.08	19042.25	17.	72.35	80.
297100	3	1458	17447	620	7419	11.59	19987.39	25.	79.00	75.
297100	4	1283	16783	499	6527	10.20	19596.71	31.	81.22	68.
297100	5	1241	7678	524	3242	5.07	21365.79	23.	83.34	76.
297200	1	911	18382	377	7603	11.88	21280.25	30.	96.50	68.
297200	2	494	16308	208	6883	10.76	23653.22	29.	108.68	69.
297300	2	137	18674	48	6548	10.23	24464.89	65.	124.79	34.
297300	3	791	2190	254	704	1.10	24728.60	85.	145.36	15.
297400	2	81	2662	24	804	1.26	44774.04	96.	266.50	4.
297400	3	2102	4816	648	1484	2.32	41011.76	80.	197.28	19.
297500	1	454	1386	169	517	0.81	26218.75	35.	125.73	64.
297500	2	701	7447	247	2624	4.10	28428.74	85.	138.30	12.
297500	3	1256	8502	400	2624	4.10	29436.18	85.	148.84	14.
297600	1	766	4828	456	2874	4.49	35493.75	16.	135.13	84.
297600	2	907	10262	384	4344	6.79	22765.82	25.	115.39	74.
297600	3	1213	10985	535	4845	7.57	23473.40	33.	126.92	64.
297600	4	1254	15343	518	6338	9.90	19949.46	40.	120.97	59.

SOURCE: U.S. CENSUS, 1970

Table 13

POPULATION AND HOUSING CHARACTERISTICS

LOS ANGELES COUNTY COASTAL ZONE

1000-YARD PERMIT AREA, HOUSING UNITS AT ADDRESS*

LONG BEACH SECTOR

CENSUS TRACT	BLOCK GROUP	PERCENT OF AREA WITHIN PERMIT AREA	TOTAL HOUSING UNITS	ONE UNIT	TWO-FOUR UNITS	FIVE-NINE UNITS	TEN-OR-MORE UNITS	MOBILE HOMES
574600	2	31	588	177	7	52	228	0
575800	4	33	492	99	74	55	131	0
575800	5	58	869	189	112	83	277	4
575900	2	81	664	29	26	29	536	3
575900	3	84	813	99	78	92	446	1
575900	4	13	568	75	85	77	281	2
575900	5	94	409	85	45	71	169	0
575900	6	100	271	47	21	38	138	0
575900	7	100	171	27	8	21	105	0
575900	8	100	63	5	3	16	35	0
576000	1	100	86	1	0	6	77	1
576000	2	100	92	9	8	12	60	0
576000	3	100	361	23	36	40	236	2
576100	1	100	854	15	16	32	754	2
576100	3	100	197	3	4	5	180	3
576100	4	100	643	15	17	19	562	1
576200	1	5	417	61	28	32	184	0
576200	2	92	464	57	14	90	247	2
576200	3	86	665	44	32	51	471	2
576200	6	100	234	8	9	18	183	7
576500	2	79	598	108	61	83	196	0
576500	3	100	538	79	32	31	324	2
576500	4	79	739	93	72	138	306	0
576500	5	3	1079	221	88	170	463	1
576500	6	26	613	113	54	97	236	1
576500	7	100	489	31	7	79	306	4
576600	1	100	370	41	26	41	175	1
576600	2	100	1339	47	46	54	1007	10
576600	3	100	621	51	30	77	341	0
576600	4	100	653	62	31	44	370	0
576600	5	100	803	45	36	57	541	1
576600	6	100	588	61	39	30	281	0
576600	7	100	760	33	20	83	455	0
576700	1	100	817	269	48	57	291	0
576700	2	100	357	103	12	27	87	1
576700	3	100	725	128	55	97	360	0
576800	2	15	864	255	133	167	223	0
576800	3	45	670	241	143	86	148	0
576800	5	61	762	148	71	129	343	0
577000	2	11	734	268	68	146	104	0
577000	3	23	631	225	67	147	35	1
577000	4	57	491	195	60	107	46	0
577000	5	85	145	135	7	0	0	0
577100	1	83	612	306	53	81	44	0
577100	2	69	693	300	26	33	120	2
577100	3	71	556	328	42	18	53	0
577200	1	100	424	152	14	36	125	0
577200	2	100	396	56	12	56	167	2
577200	3	100	813	167	74	169	214	1
577200	4	100	911	208	73	146	289	1

Table 14

Table 14 (Continued)

577300	1	100	595	339	98	34	4	0
577300	2	100	497	80	48	146	112	1
577300	3	100	594	180	67	140	82	0
577300	4	100	738	290	168	76	44	0
577300	5	100	667	153	123	147	57	0
577300	6	100	375	71	39	138	38	0
577400	1	100	354	213	25	18	22	0
577400	2	100	471	181	62	63	63	0
577400	3	100	868	361	248	83	34	0
577400	4	100	557	241	99	60	10	0
577501	1	100	586	350	28	30	21	1
577501	2	100	536	414	25	5	15	0
577501	3	100	682	452	23	7	93	0
577502	1	100	475	168	72	35	58	0
577502	2	100	400	146	48	45	2	0
577602	1	76	731	446	0	0	1	226
577603	1	97	389	372	1	0	0	0
577603	2	100	486	352	21	16	85	0
577603	3	100	436	361	26	0	0	0
577603	4	100	501	221	43	18	148	0

SOURCE: U.S. CENSUS, 1970
*NOTE: DATA ARE FOR COMPLETE BLOCK GROUPS RATHER THAN LIMITED TO 1000-YARD BOUNDARY

L O S   A N G E L E S   C O U N T Y   C O A S T A L   Z O N E

AREAS AND POPULATION OF CENSUS BLOCK GROUPS WITHIN 1000-YARD PERMIT AREA

LONG BEACH SECTOR

CENSUS TRACT	BLOCK GROUP	AREA SQ MI	AREA ACRES	PERCENT OF TOTAL AREA OF BLK GRP	ESTIMATED PERCENT OF TOTAL POPULATION OF BLK GRP*
574800	2	0.04	28.21	31.	26.
575800	4	0.01	7.20	33.	23.
575800	5	0.10	63.47	58.	26.
575900	2	0.02	15.28	81.	67.
575900	3	0.03	20.72	84.	77.
575900	4	0.00	2.94	13.	6.
575900	5	0.03	19.25	94.	83.
575900	6	0.03	19.54	100.	100.
575900	7	0.05	31.88	100.	100.
575900	8	0.05	34.67	100.	100.
576000	1	0.19	121.80	100.	100.
576000	2	0.08	53.48	100.	100.
576000	3	0.04	26.01	100.	100.
576100	1	0.03	20.57	100.	100.
576100	3	0.04	22.63	100.	100.
576100	4	0.04	26.74	100.	100.
576200	1	0.00	2.06	5.	8.
576200	2	0.04	24.24	92.	94.
576200	3	0.04	25.27	86.	94.
576200	6	0.04	28.80	100.	100.
576500	2	0.04	25.71	79.	57.
576500	3	0.03	19.98	100.	100.
576500	4	0.05	32.32	79.	99.
576500	5	0.01	3.23	3.	8.
576500	6	0.01	6.91	26.	26.
576500	7	0.03	18.66	100.	100.
576600	1	0.03	19.25	100.	100.
576600	2	0.20	129.44	100.	100.
576600	3	0.03	20.28	100.	100.
576600	4	0.04	23.07	100.	100.
576600	5	0.03	19.69	100.	100.
576600	6	0.03	21.30	100.	100.
576600	7	0.03	20.28	100.	100.
576700	1	0.10	65.53	100.	100.
576700	2	0.13	80.81	100.	100.
576700	3	0.09	55.54	100.	100.
576800	2	0.01	5.00	15.	27.
576800	3	0.04	23.21	45.	40.
576800	5	0.03	18.22	61.	44.
577000	2	0.01	5.88	11.	11.
577000	3	0.02	10.87	23.	11.
577000	4	0.07	47.60	57.	40.
577000	5	0.30	194.38	85.	100.
577100	1	0.06	49.37	80.	82.
577100	2	0.06	41.14	69.	69.
577100	3	0.07	45.40	71.	70.
577200	1	0.16	102.41	100.	100.
577200	2	0.12	79.34	100.	100.
577200	3	0.07	43.64	100.	100.
577200	4	0.10	62.00	100.	100.

Table 15

577300	1	0.06	38.05	100.	100.
577300	2	0.04	27.18	100.	100.
577300	3	0.05	29.24	100.	100.
577300	4	0.07	45.55	100.	100.
577300	5	0.06	36.73	100.	100.
577300	6	0.07	44.81	100.	100.
577400	1	0.08	48.78	100.	100.
577400	2	0.04	24.68	100.	100.
577400	3	0.08	48.78	100.	100.
577400	4	0.06	37.76	100.	100.
577501	1	0.14	89.48	100.	100.
577501	2	0.08	54.07	100.	100.
577501	3	0.11	69.35	100.	100.
577502	1	0.06	40.55	100.	100.
577502	2	0.09	56.12	100.	100.
577602	1	0.41	261.96	76.	94.
577603	1	0.19	122.98	97.	100.
577603	2	0.38	240.22	100.	100.
577603	3	0.17	108.28	100.	100.
577603	4	0.28	179.98	100.	100.
576100	2	0.13	82.68	100.	NO POPULATION
577601	9	1.26	810.11	81.	NO POPULATION

*PERCENT OF POPULATION IN 1000-YARD AREA ESTIMATED BY PHILLIP SYMONDS, CENTER FOR URBAN AFFAIRS,USC

Table 15 (Continued)

L O S   A N G E L E S   C O U N T Y   C O A S T A L   Z O N E

1000-YARD PERMIT AREA

LONG BEACH SECTOR

CENSUS TRACT	BLOCK GROUP	POPULATION	POPULATION DENSITY/ SQ MI	NUMBER OF HOUSING UNITS	HOUSING DENSITY/ SQ MI	HOUSING DENSITY/ ACRE	OWNER OCCUPIED HOUSING: MEAN VALUE	OWNER OCCUPIED HOUSING: PERCENT OF TOTAL HOUSING	RENTER OCCUPIED HOUSING: AVERAGE RENT	RENTER OCCUPIED HOUSING: PERCENT OF TOTAL HOUSING
574800	2	287	6518	152	3468	5.42	54638.70	32.	148.43	63.
575800	4	198	17624	113	10059	15.72	20314.29	11.	84.05	84.
575800	5	427	4312	225	2278	3.56	17620.69	11.	90.58	88.
575900	2	482	20233	444	18633	29.12	48687.50	24.	66.18	73.
575900	3	911	29165	626	19339	30.22	17022.73	18.	71.55	80.
575900	4	44	9670	34	7422	11.60	26519.23	29.	68.15	68.
575900	5	569	18629	339	11288	17.64	17819.44	6.	82.51	88.
575900	6	426	13952	271	8875	13.87	17875.00	6.	84.98	93.
575900	7	251	5239	171	3432	5.36	16950.00	5.	73.34	87.
575900	8	78	1439	63	1162	1.82	0.0	0.	74.26	97.
576000	1	88	462	86	451	0.71	0.0	1.	48.18	90.
576000	2	138	1651	92	1100	1.72	0.0	5.	67.95	93.
576000	3	447	11600	361	8884	13.88	0.0	2.	67.53	96.
576100	1	571	30211	854	26571	41.52	0.0	34.	80.97	62.
576100	3	216	6109	197	5572	8.71	0.0	1.	72.89	96.
576100	4	743	17783	643	15389	24.05	0.0	22.	75.71	75.
576200	1	52	16478	33	10379	16.22	20611.11	12.	85.07	85.
576200	2	579	15311	436	11514	17.99	25107.14	13.	83.37	87.
576200	3	705	20139	625	15831	24.74	26035.71	25.	75.65	73.
576200	6	248	5511	234	5200	8.13	0.0	1.	67.79	97.
576500	2	472	11761	340	8484	13.26	19315.21	28.	87.14	69.
576500	3	846	27096	538	17231	26.92	27685.89	36.	98.21	62.
576500	4	1111	22013	731	14485	22.63	21146.55	11.	98.86	88.
576500	5	152	30206	86	17091	26.71	19972.22	12.	96.55	83.
576500	6	269	24998	159	14771	23.08	17675.93	12.	86.97	87.
576500	7	744	25519	489	16772	26.21	0.0	26.	91.58	73.
576600	1	532	17690	370	12303	19.22	25550.00	23.	90.98	74.
576600	2	1810	8949	1339	6620	10.34	[illegible]6950.00	27.	150.76	68.
576600	3	985	31091	621	19602	30.63	25812.50	20.	109.14	80.
576600	4	995	25109	653	18117	28.31	23166.66	27.	92.40	72.
576600	5	1066	34652	803	26103	40.79	37950.00	23.	98.43	75.
576600	6	839	27007	588	17664	27.60	23218.75	19.	98.30	76.
576600	7	1031	32543	760	23989	37.48	23450.00	31.	86.22	68.
576700	1	1509	14738	817	7979	12.47	34293.65	29.	149.30	70.
576700	2	669	5298	357	2827	4.42	46018.18	29.	120.59	69.
576700	3	1336	15395	725	8354	13.05	31754.23	37.	119.71	62.
576800	2	416	55900	233	29887	46.70	23997.73	19.	115.97	81.
576800	3	527	14556	267	7388	11.54	26114.09	33.	117.01	66.
576800	5	541	19011	335	11778	18.40	24195.45	32.	103.77	68.
577000	2	157	17177	80	8792	13.74	18369.40	23.	98.51	75.
577000	3	136	8042	69	4085	6.38	22834.27	18.	106.79	81.
577000	4	395	5323	196	2640	4.13	19961.27	20.	112.82	79.
577000	5	373	1228	145	477	0.75	41497.91	85.	111.70	14.
577100	1	1058	13724	501	6505	10.17	22846.27	33.	119.27	66.
577100	2	910	14470	478	7438	11.62	25542.75	33.	133.41	65.
577100	3	774	10913	389	5486	8.57	30941.02	41.	118.88	57.
577200	1	796	4974	424	2649	4.14	34272.50	37.	136.37	63.
577200	2	660	5324	396	3194	4.99	43115.38	26.	141.58	73.
577200	3	1436	21061	813	11924	18.63	41364.58	20.	125.09	79.
577200	4	1575	16257	911	9403	14.69	30051.63	18.	129.99	80.

Table 16 POPULATION AND HOUSING CHARACTERISTICS

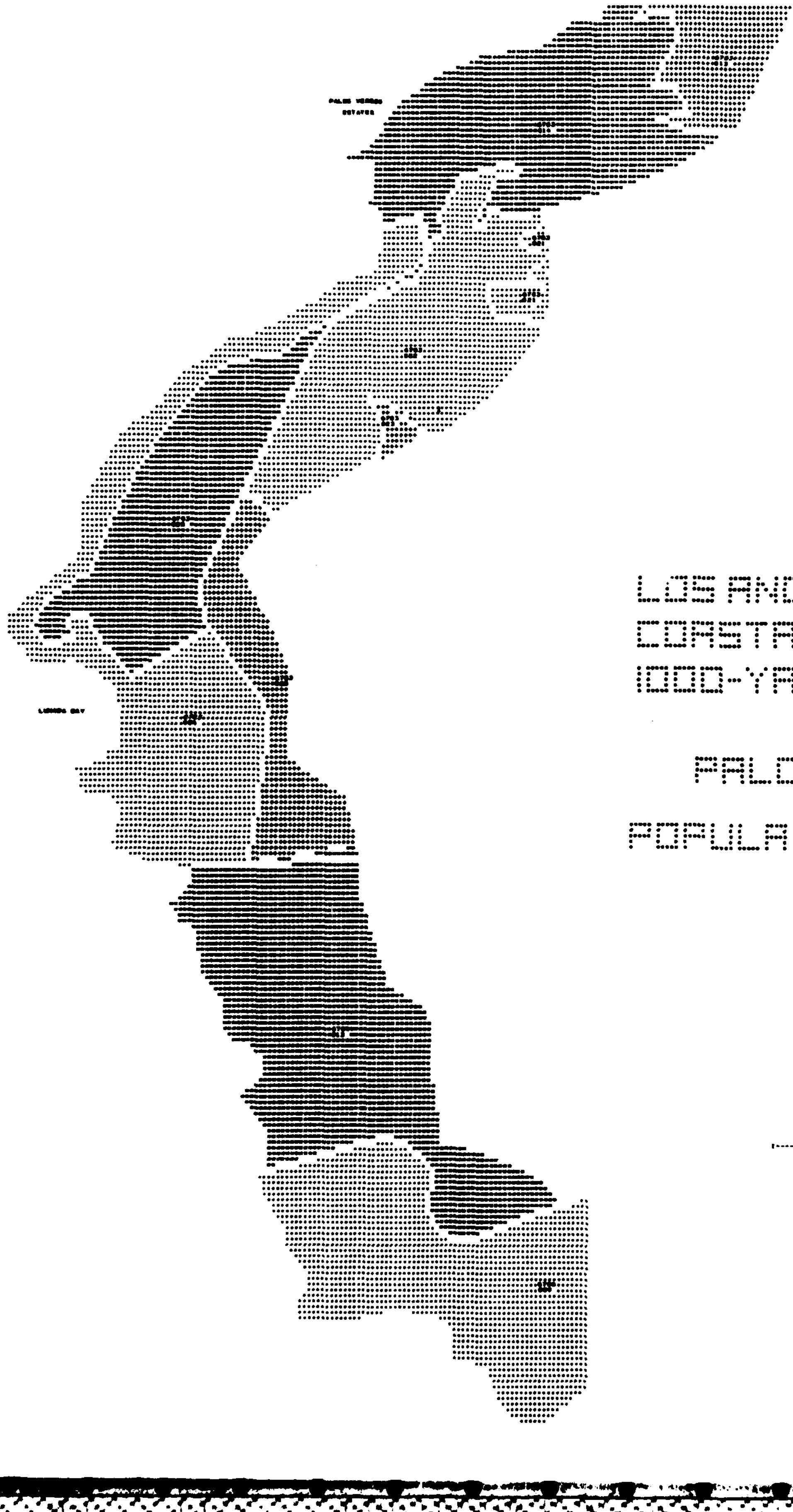
Table 16 (Continued)

577300	1	1162	19543	595	10007	15.64	29461.72	42.	152.51	56.
577300	2	784	18460	497	11702	18.28	35651.31	16.	149.60	82.
577300	3	1273	27865	594	13002	20.32	41550.40	25.	120.55	74.
577300	4	1396	19616	738	10370	16.20	29376.92	36.	133.95	62.
577300	5	1134	19758	667	11621	18.16	31686.75	20.	138.31	78.
577300	6	626	8540	375	5355	8.37	34808.82	16.	131.11	83.
577400	1	795	10430	354	4644	7.26	39410.13	55.	146.33	44.
577400	2	888	23024	471	12212	19.08	37823.91	38.	149.46	61.
577400	3	1677	22003	868	11388	17.79	32841.77	36.	124.76	64.
577400	4	1110	18813	557	9440	14.75	30168.83	38.	132.96	61.
577501	1	1228	8783	586	4191	6.55	36026.16	52.	134.60	47.
577501	2	1208	14259	536	6344	9.91	43757.50	66.	148.53	32.
577501	3	1611	14867	682	6294	9.83	44058.02	57.	209.28	41.
577502	1	838	13225	475	7496	11.71	51396.66	23.	166.24	72.
577502	2	753	8586	400	4561	7.13	55163.33	32.	180.84	65.
577602	1	1558	4783	687	1678	2.62	35448.92	95.	183.72	5.
577603	1	1153	6000	389	2024	3.16	42153.06	90.	170.81	9.
577603	2	1107	2949	486	1294	2.02	37495.21	67.	187.52	32.
577603	3	1036	6123	436	2576	4.03	33639.88	67.	122.01	31.
577603	4	1031	3666	501	1781	2.78	34184.21	35.	149.98	64.

SOURCE: U.S. CENSUS, 1970

Figure 11. Legend

```
C  POPULATION DENSITY (PER SQUARE MILE)

C  PALOS VERDES SECTOR

C  1000-YARD PERMIT AREA OF L. A. COUNTY COASTAL ZONE



DATA VALUE EXTREMES ARE          0.0       6318.58


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL CNLY)

  MINIMUM       0.0       497.85   2500.00   5000.00
  MAXIMUM     497.85     2500.00   5000.00   6318.58


PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

              7.88      31.69      39.57      20.87


 FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL         1         2          3         4
          =========================================
           ---------  .........  =========  +++++++++
           ---------  .........  =========  +++++++++
  SYMBOLS  ---- ----  .... ....  ==== ====  ++++ ++++
           ---------  .........  =========  +++++++++
           ---------  .........  =========  +++++++++
          =========================================
  FREQ.         1         4          4         3
          1  I-- --I   I.. ..I   I== ==I   I++ ++I
          2            I.. ..I   I== ==I   I++ ++I
          3            I.. ..I   I== ==I   I++ ++I
          4            I.. ..I   I== ==I
```



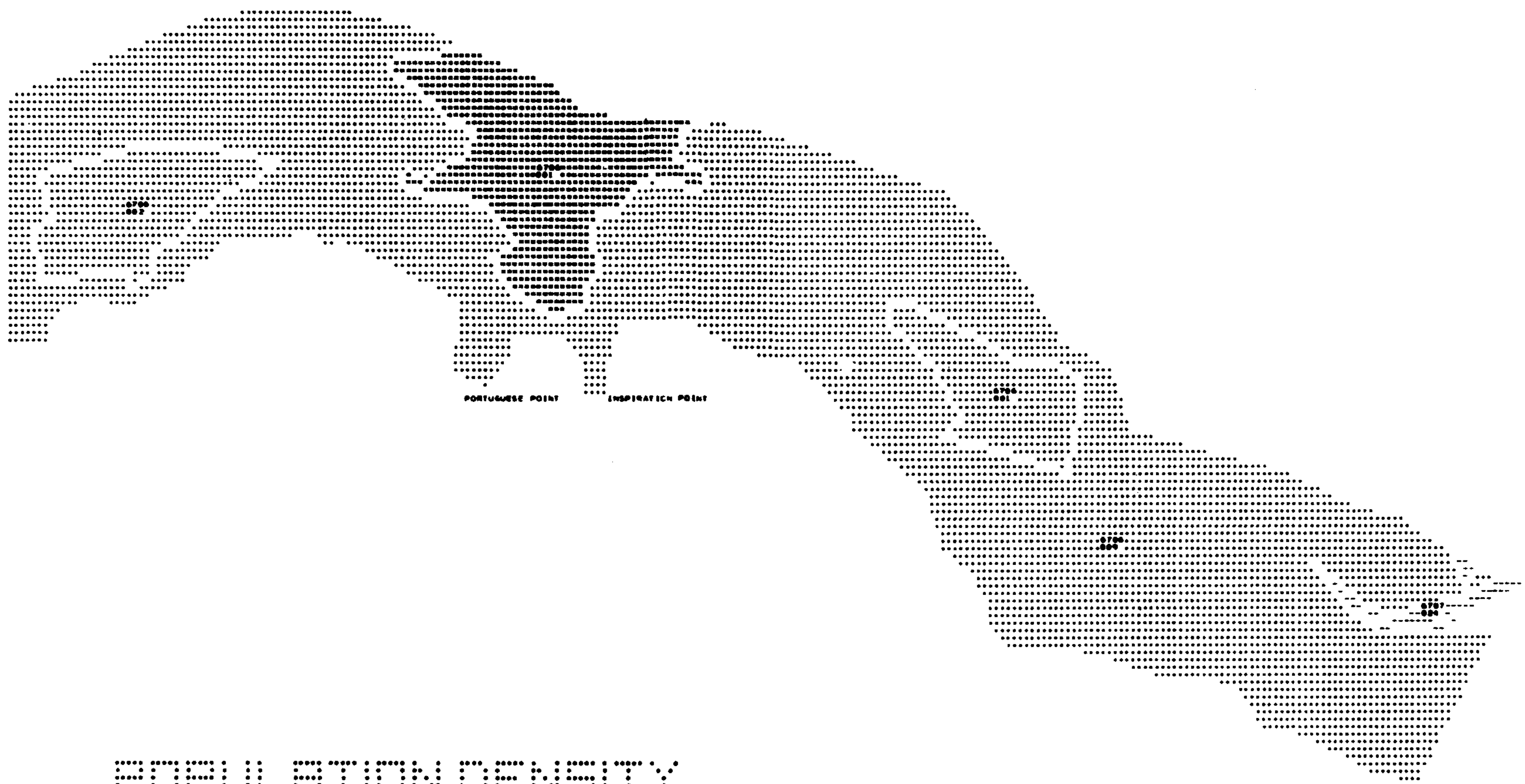
LOS ANGELES COUNTY
COASTAL ZONE
1000-YARD PERMIT AREA

PALOS VERDES

POPULATION DENSITY
1970

Figure 12. Legend

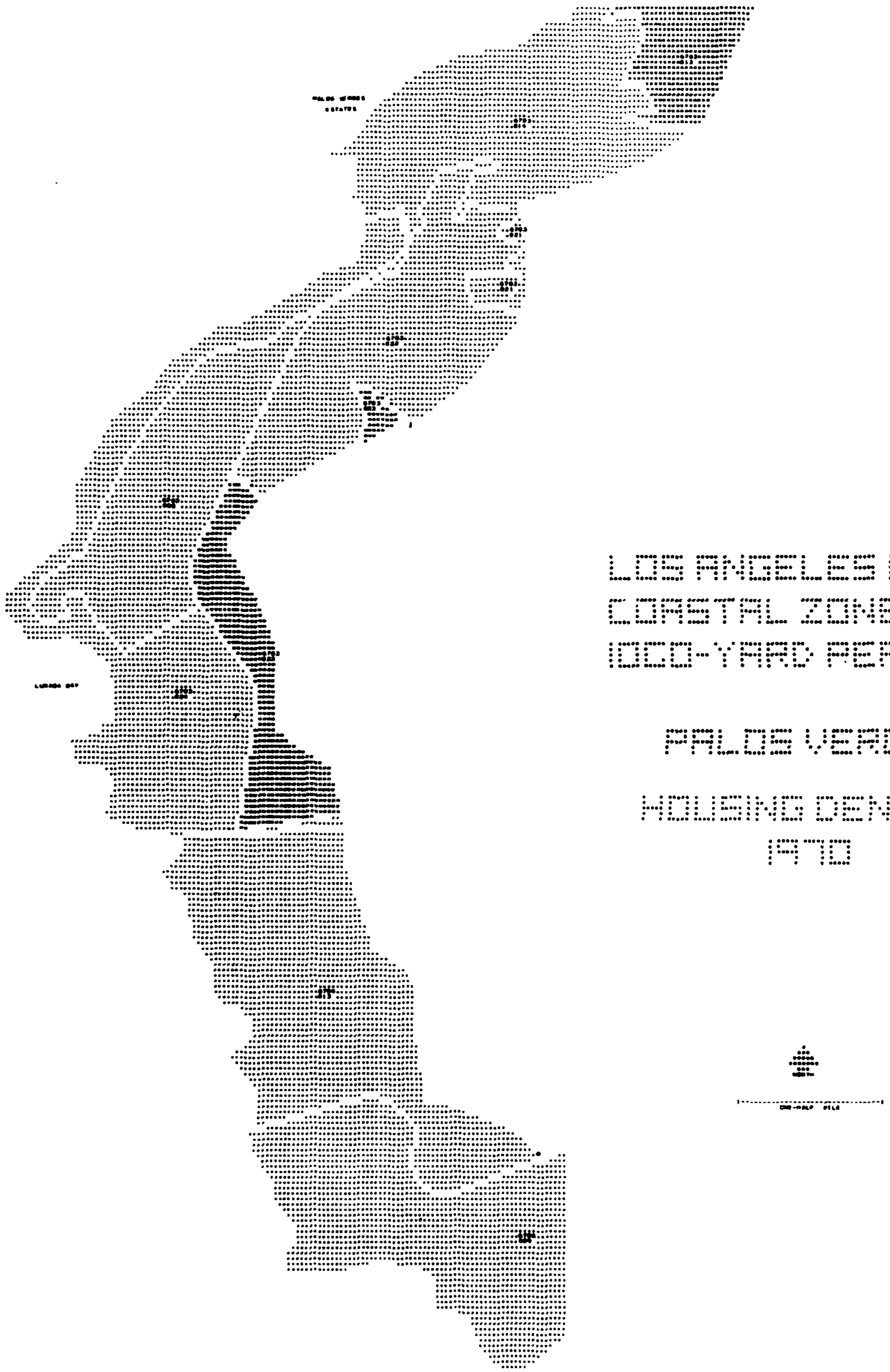
```
C  POPULATION DENSITY (PER SQUARE MILE)

C  PALOS VERDES SECTOR

C  1000-YARD PERMIT AREA OF L. A. COUNTY COASTAL ZONE


DATA VALUE EXTREMES ARE          0.0       6318.58


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL CNLY)

  MINIMUM        0.0      497.85    2500.00    5000.00
  MAXIMUM      497.85    2500.00    5000.00    6318.58


PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

                 7.88      31.69      39.57      20.87


 FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
   LEVEL          1          2          3          4
           ========================================
            ---------  .........  =========  +++++++++
            ---------  .........  =========  +++++++++
   SYMBOLS  ---- ----  .... ....  ==== ====  ++++ ++++
            ---------  .........  =========  +++++++++
            ---------  .........  =========  +++++++++
           ========================================
   FREQ.          1          4          4          3
          1  I-- --I    I.. ..I    I== ==I    I++ ++I
          2             I.. ..I    I== ==I    I++ ++I
          3             I.. ..I    I== ==I    I++ ++I
          4             I.. ..I    I== ==I
```



POPULATION DENSITY
1970

Figure 13. Legend

```
C  HOUSING DENSITY (UNITS PER SQUARE MILE)

C  PALOS VERDES SECTOR

C  1000-YARD PERMIT AREA OF L. A. COUNTY COASTAL ZONE


DATA VALUE EXTREMES ARE          0.0       2803.36


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM      0.0      125.66   1280.00   2500.00
  MAXIMUM    125.66    1280.00   2500.00   2803.36


PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

             4.48      41.18     43.52     10.82


FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL         1         2         3         4
         ========================================
          --------- ......... ========= +++++++++
          --------- ......... ========= +++++++++
  SYMBOLS ---- ---- .... .... ==== ==== ++++ ++++
          --------- ......... ========= +++++++++
          --------- ......... ========= +++++++++
         ========================================
  FREQ.         1         8         2         1
           1  I-- --I   I.. ..I   I== ==I   I++ ++I
           2            I.. ..I   I== ==I
           3            I.. ..I
           4            I.. ..I
           5            I.. ..I
           6            I.. ..I
           7            I.. ..I
           8            I.. ..I
```



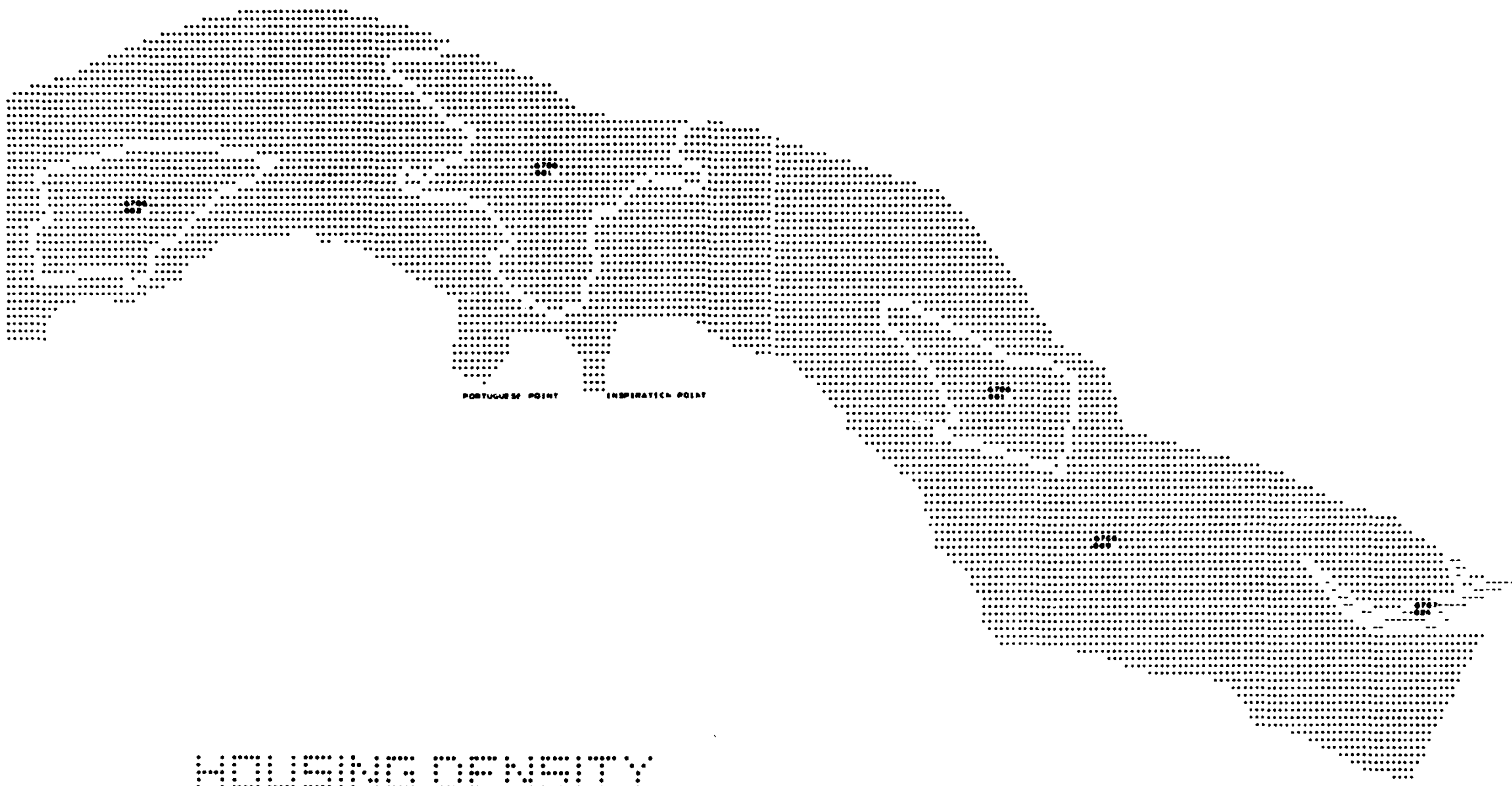
LOS ANGELES COUNTY
COASTAL ZONE
1000-YARD PERMIT AREA

PALOS VERDES

HOUSING DENSITY
1970

Figure 14. Legend

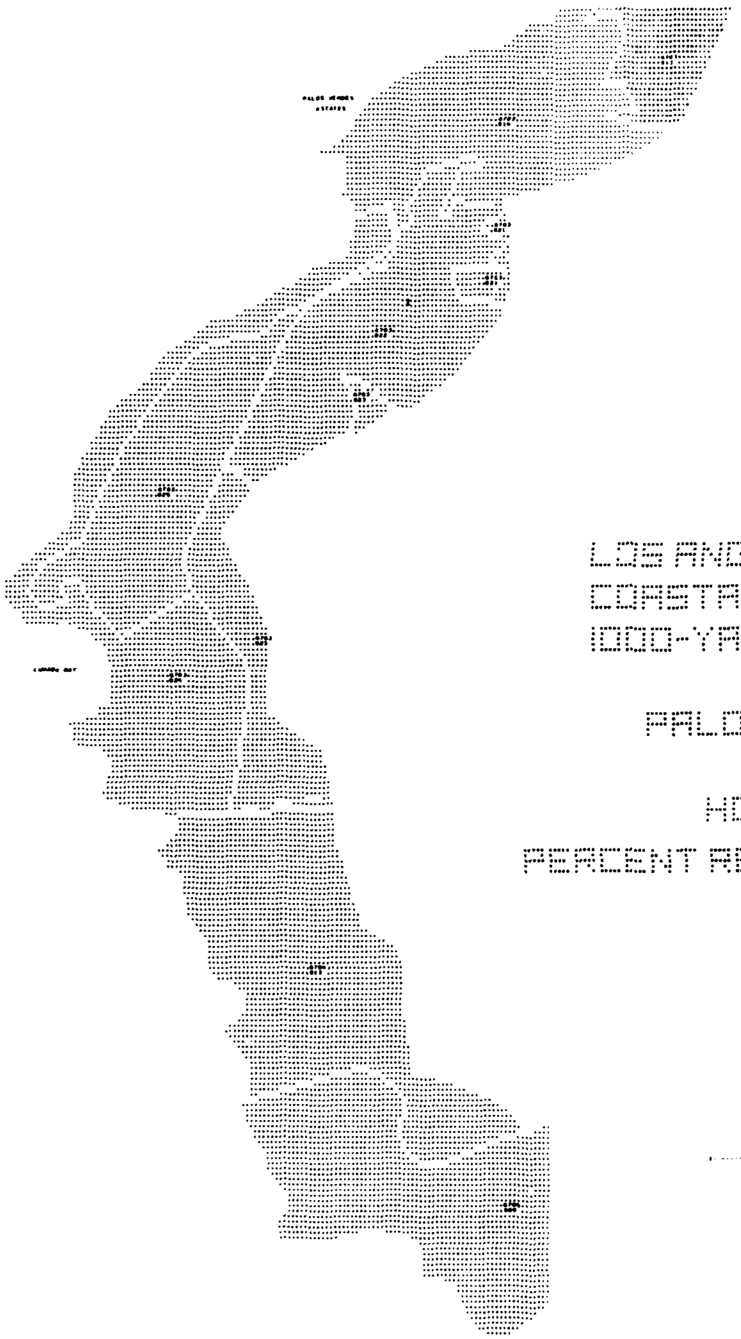
```
C  HOUSING DENSITY (UNITS PER SQUARE MILE)

C  PALOS VERDES SECTOR

C  1000-YARD PERMIT AREA OF L. A. COUNTY COASTAL ZONE


DATA VALUE EXTREMES ARE           0.0        2803.36


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
       ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM       0.0       125.66    1280.00    2500.00
  MAXIMUM     125.66     1280.00    2500.00    2803.36


PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               4.48      41.18      43.52      10.82


FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1          2          3          4
         ==========================================
          ---------  .........  =========  +++++++++
          ---------  .........  =========  +++++++++
  SYMBOLS ---- ----  .... ....  ==== ====  ++++ ++++
          ---------  .........  =========  +++++++++
          ---------  .........  =========  +++++++++
         ==========================================
  FREQ.          1          8          2          1
       1    I-- --I    I.. ..I    I== ==I    I++ ++I
       2               I.. ..I    I== ==I
       3               I.. ..I
       4               I.. ..I
       5               I.. ..I
       6               I.. ..I
       7               I.. ..I
       8               I.. ..I
```



HOUSING DENSITY
1970

Figure 15. Legend

```
C   PERCENT OF HOUSING RENTER OCCUPIED
C  PALOS VERDES SECTOR
C  1000-YARD PERMIT AREA OF L. A. COUNTY COASTAL ZONE


DATA VALUE EXTREMES ARE          0.0          0.40


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
       ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM       0.0        0.04       0.20       0.30
  MAXIMUM       0.04       0.20       0.30       0.40

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               10.00      40.00      25.00      25.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL            1          2          3          4
          ========================================
           ---------  .........  =========  OOOOOOOOO
           ---------  .........  =========  OOOOOOOOO
  SYMBOLS  ---- ----  .... ....  ==== ====  OOOO OOOO
           ---------  .........  =========  OOOOOOOOO
           ---------  .........  =========  OOOOOOOOO
          ========================================
  FREQ.            1          9          1          1
         1   I-- --I    I.. ..I    I== ==I    IOO OOI
         2              I.. ..I
         3              I.. ..I
         4              I.. ..I
         5              I.. ..I
         6              I.. ..I
         7              I.. ..I
         8              I.. ..I
         9              I.. ..I
```



LOS ANGELES COUNTY
COASTAL ZONE
1000-YARD PERMIT AREA

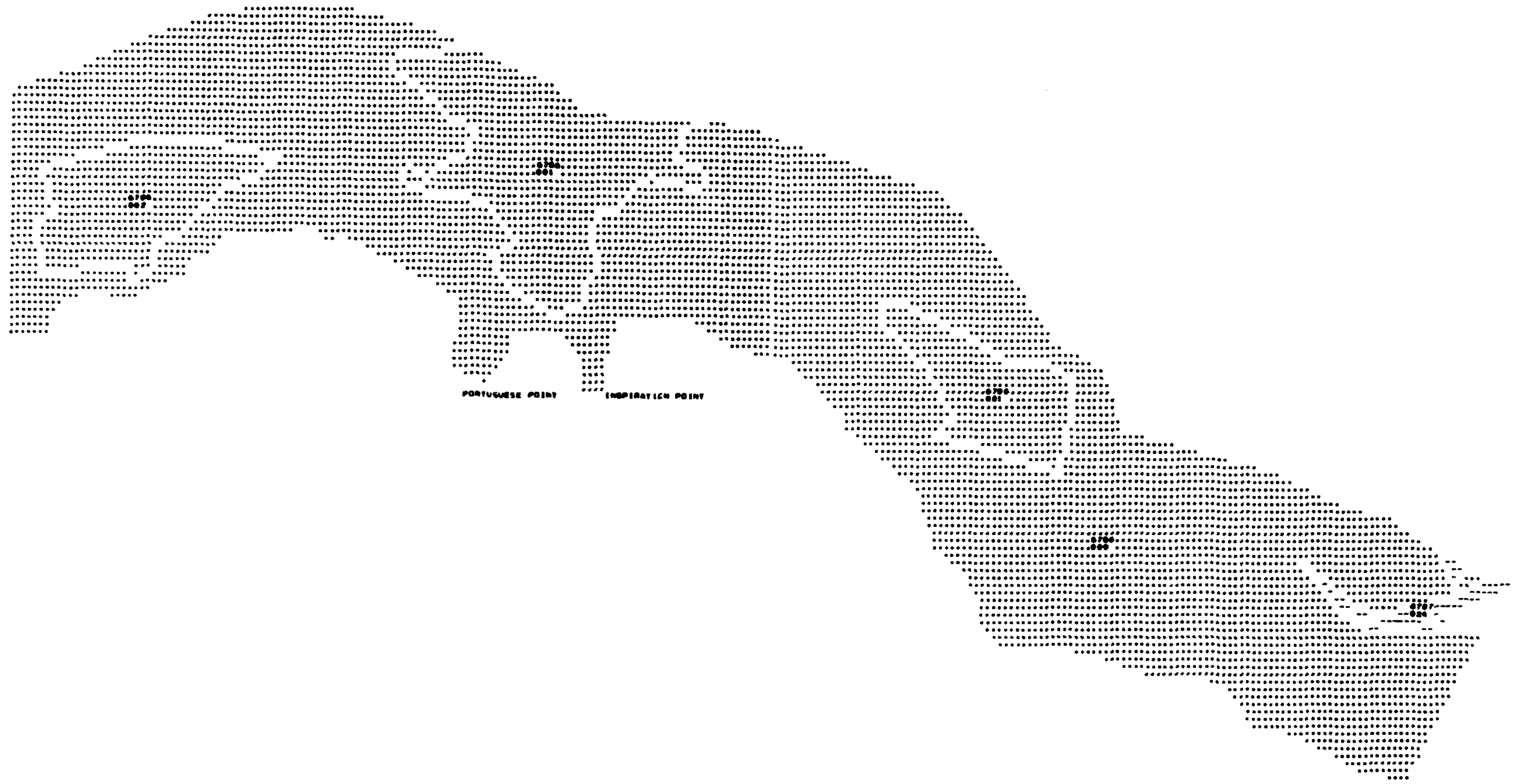
PALOS VERDES

HOUSING
PERCENT RENTER OCCUPIED

1970

Figure 16. Legend

```
C   PERCENT OF HOUSING RENTER OCCUPIED
C  PALOS VERDES SECTOR
C  1000-YARD PERMIT AREA OF L. A. COUNTY COASTAL ZONE


DATA VALUE EXTREMES ARE          0.0          0.40


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM        0.0         0.04        0.20        0.30
  MAXIMUM        0.04        0.20        0.30        0.40

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               10.00       40.00       25.00       25.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1          2          3          4
          ==========================================
           ---------- ......... ========= OOOOOOOOO
           ---------- ......... ========= OOOOOOOOO
  SYMBOLS  ---- ----  .... .... ==== ==== OOOO OOOO
           ---------- ......... ========= OOOOOOOOO
           ---------- ......... ========= OOOOOOOOO
          ==========================================
  FREQ.          1          9          1          1
          1   I-- --I    I.. ..I    I== ==I   IOO OOI
          2              I.. ..I
          3              I.. ..I
          4              I.. ..I
          5              I.. ..I
          6              I.. ..I
          7              I.. ..I
          8              I.. ..I
          9              I.. ..I
```



HOUSING-PERCENT RENTER OCCUPIED
1970

Figure 17. Legend

C AVERAGE RENT. 1970

C PALOS VERDES SECTOR

C 1000-YARD PERMIT AREA OF L. A. COUNTY COASTAL ZONE

DATA VALUE EXTREMES ARE 0.0 349.94

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.0	197.75	225.00	275.00
MAXIMUM	197.75	225.00	275.00	349.94

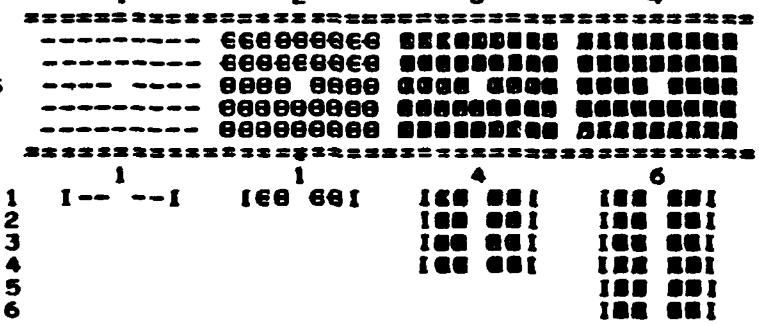
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

56.51	7.79	14.29	21.42

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

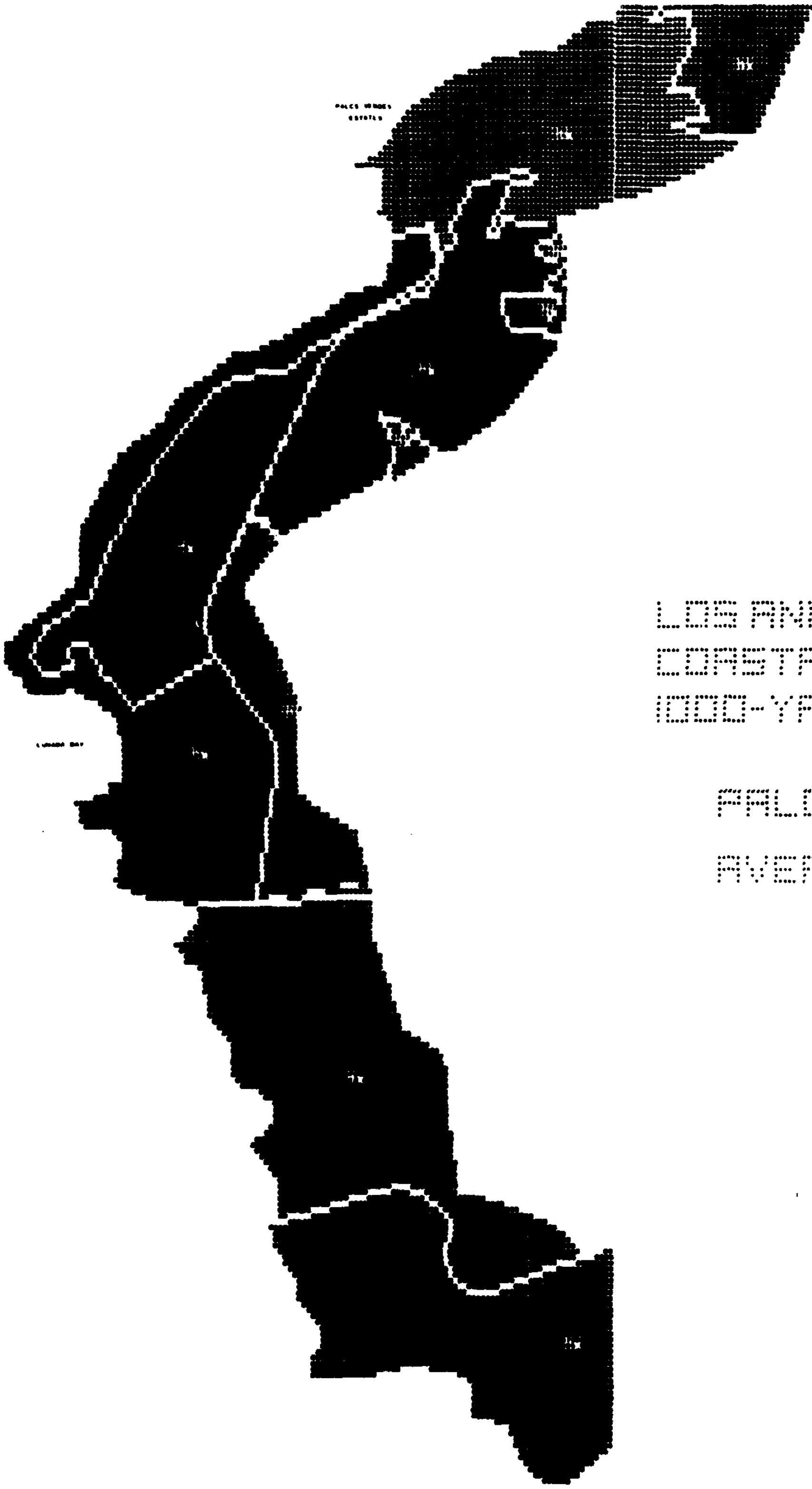
LEVEL 1 2 3 4

SYMBOLS



FREQ. 1 1 4 6

1
2
3
4
5
6



LOS ANGELES COUNTY
COASTAL ZONE
1000-YARD PERMIT AREA

PALOS VERDES

AVERAGE RENT
1970

Figure 18. Legend

C AVERAGE RENT. 1970

C PALOS VERDES SECTOR

C 1000-YARD PERMIT AREA OF L. A. COUNTY COASTAL ZONE

DATA VALUE EXTREMES ARE 0.0 349.94

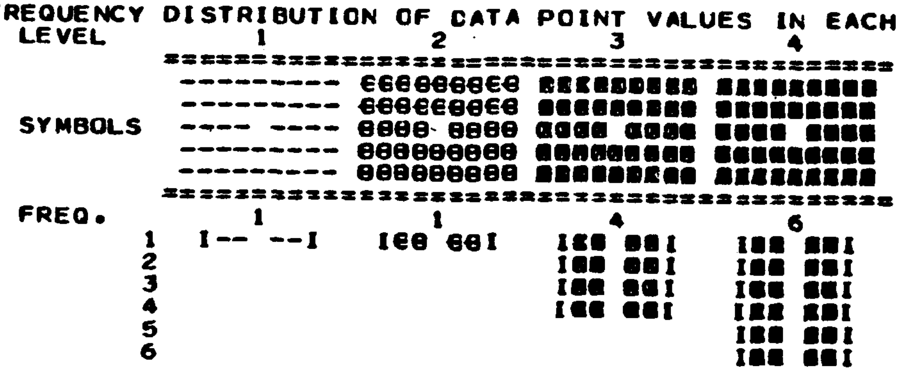
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

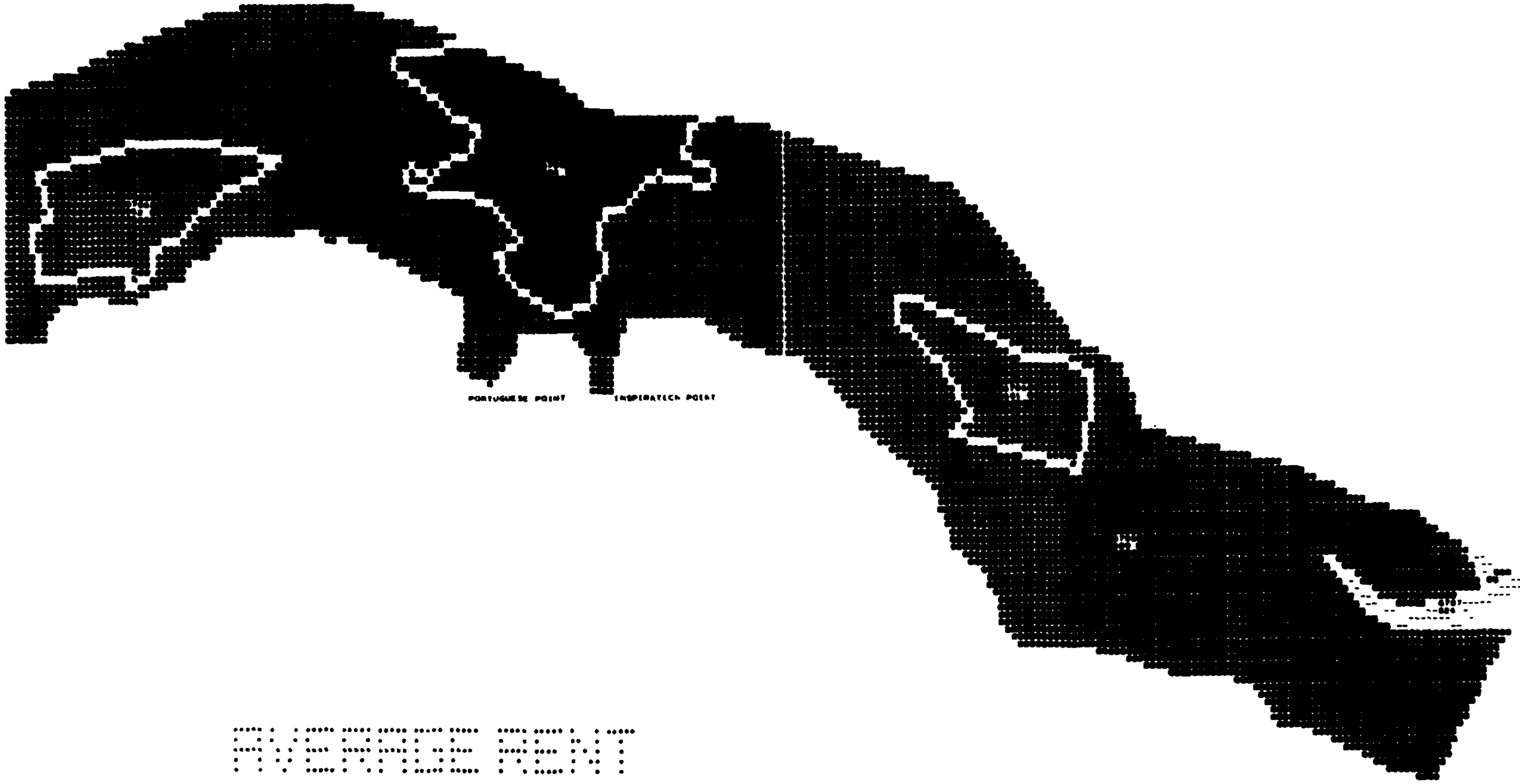
MINIMUM	0.0	197.75	225.00	275.00
MAXIMUM	197.75	225.00	275.00	349.94

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

56.51	7.79	14.29	21.42

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

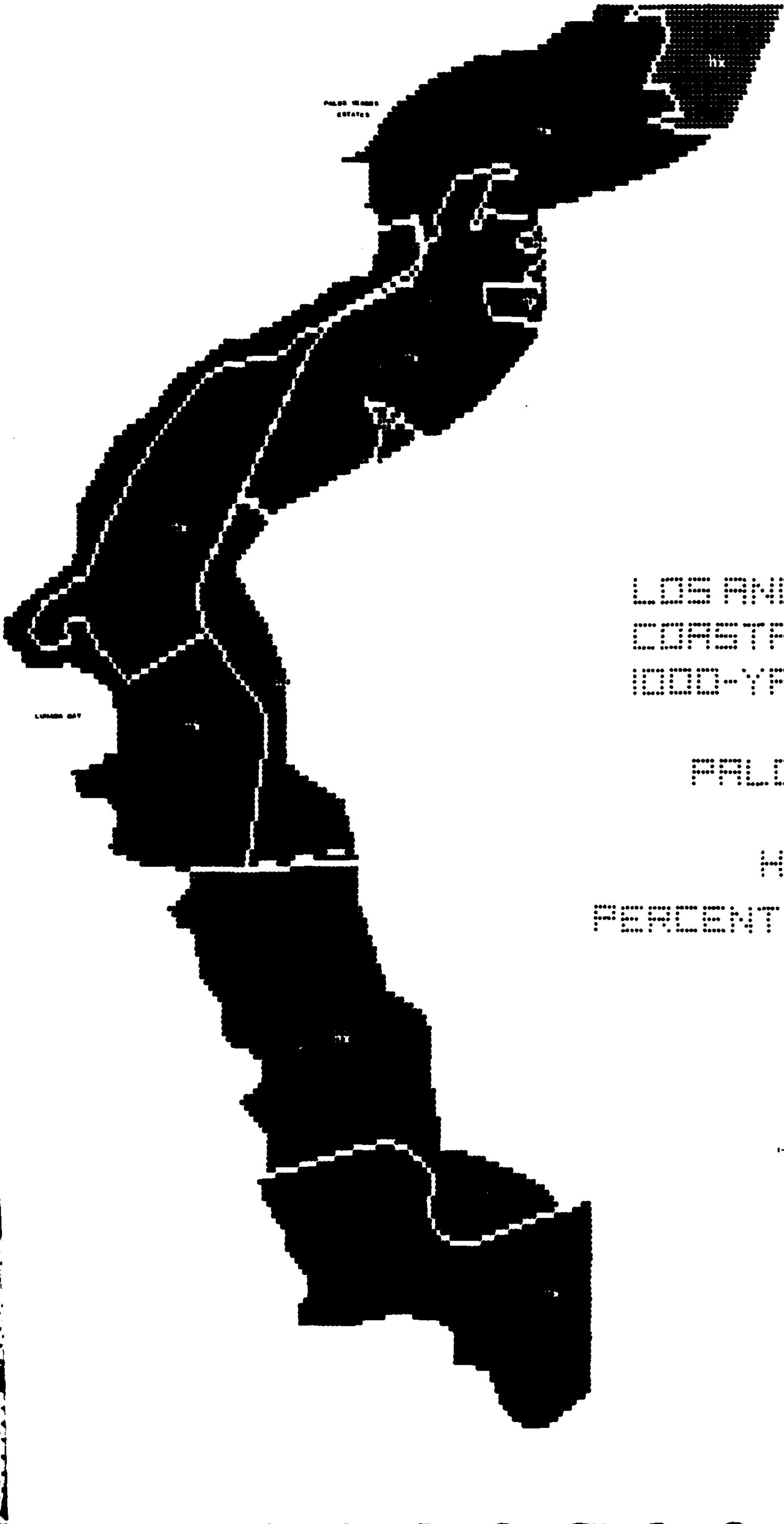




AVERAGE RENT
1970

Figure 19. Legend

```
C   PERCENT OF HOUSING OWNER OCCUPIED

C  PALOS VERDES SECTOR

C  1000-YARD PERMIT AREA OF L. A. COUNTY CCASTAL ZONE


DATA VALUE EXTREMES ARE          0.0          0.96


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL CNLY)

  MINIMUM       0.0        0.58        0.60        0.70        0.80        0.90
  MAXIMUM       0.58       0.60        0.70        0.80        0.90        0.96


PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               60.42       2.08       10.42       10.42       10.42        6.25


FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL         1          2          3          4          5          6
          ==================================================================
          ---------  XXXXXXXXX  *********  @@@@@@@@@  █████████  █████████
          ---------  XXXXXXXXX  *********  @@@@@@@@@  █████████  █████████
  SYMBOLS ---- ----  XXXX XXXX  **** ****  @@@@ @@@@  ████ ████  ████ ████
          ---------  XXXXXXXXX  *********  @@@@@@@@@  █████████  █████████
          ---------  XXXXXXXXX  *********  @@@@@@@@@  █████████  █████████
          ==================================================================
  FREQ.         1          1          0          1          3          6
        1   I-- --I   IXX XXI             I@@ @@I    I██ ██I    I██ ██I
        2                                            I██ ██I    I██ ██I
        3                                            I██ ██I    I██ ██I
        4                                                       I██ ██I
        5                                                       I██ ██I
        6                                                       I██ ██I
```



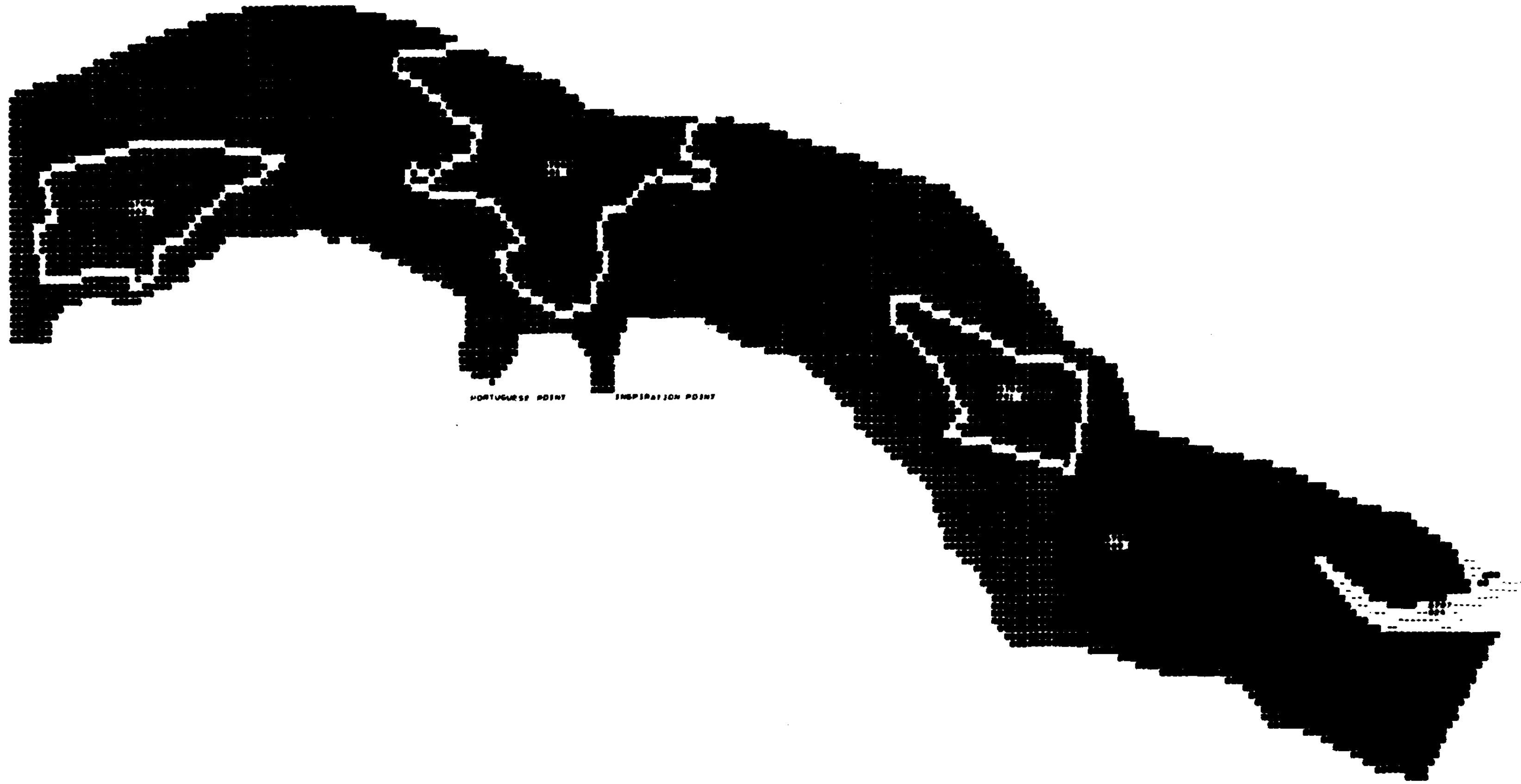
LOS ANGELES COUNTY
COASTAL ZONE
1000-YARD PERMIT AREA

PALOS VERDES

HOUSING
PERCENT OWNER OCCUPIED
1970

Figure 20. Legend

```
C   PERCENT OF HOUSING OWNER OCCUPIED

C  PALOS VERDES SECTOR

C  1000-YARD PERMIT AREA OF L. A. COUNTY CCASTAL ZONE


DATA VALUE EXTREMES ARE          0.0          0.96


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM       0.0       0.58      0.60      0.70      0.80      0.90
  MAXIMUM       0.58      0.60      0.70      0.80      0.90      0.96

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

              60.42      2.08     10.42     10.42     10.42      6.25

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL         1         2         3         4         5         6
           ==============================================================
            --------- XXXXXXXXX ********* 888888888 █████████ █████████
            --------- XXXXXXXXX ********* 888888888 █████████ █████████
  SYMBOLS   ---- ---- XXXX XXXX **** **** 8888 8888 ████ ████ ████ ████
            --------- XXXXXXXXX ********* 888888888 █████████ █████████
            --------- XXXXXXXXX ********* 888888888 █████████ █████████
           ==============================================================
  FREQ.         1         1         0         1         3         6
           1  I-- --I   IXX XXI             I88 88I   I██ ██I   I██ ██I
           2                                          I██ ██I   I██ ██I
           3                                          I██ ██I   I██ ██I
           4                                                    I██ ██I
           5                                                    I██ ██I
           6                                                    I██ ██I
```

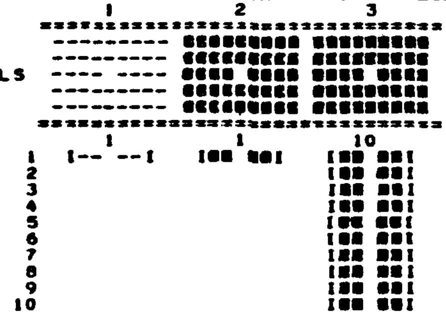


HOUSING- PERCENT OWNER OCCUPIED

1970

Figure 21. Legend

```
C   OWNER OCCUPIED HOUSING UNITS. AVERAGE VALUE
C  PALOS VERDES SECTOR
C  1000-YARD PERMIT AREA OF L. A. COUNTY COASTAL ZCNE


DATA VALUE EXTREMES ARE          0.0      58786.21


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
       ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM        0.0    49698.85  50000.00
  MAXIMUM   49698.85    50000.00  58786.21

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               84.54       0.51      14.95

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL            1          2          3

  SYMBOLS

  FREQ.            1          1         10
```



LOS ANGELES COUNTY
COASTAL ZONE
1000-YARD PERMIT AREA

PALOS VERDES

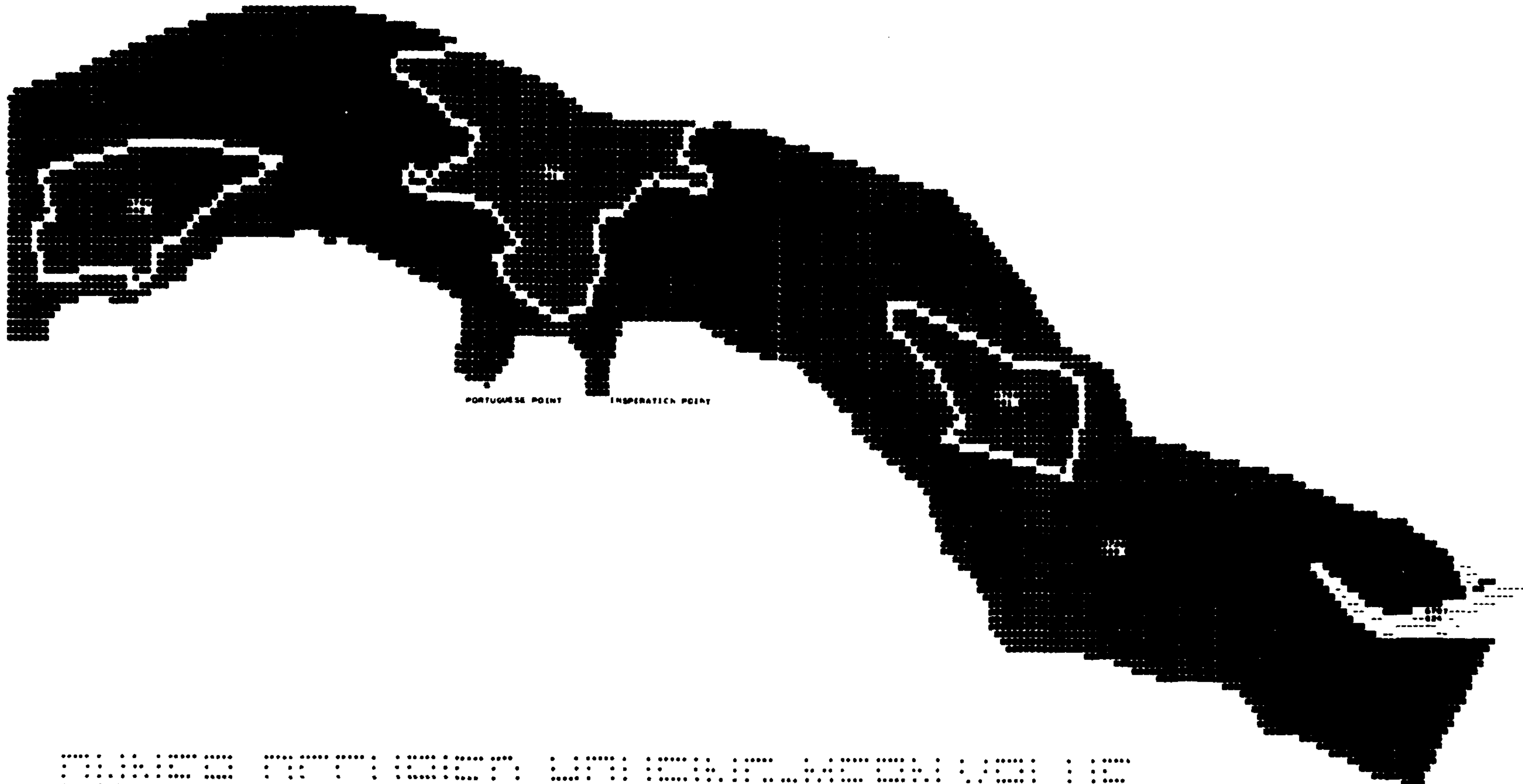
OWNER OCCUPIED HOUSING

MEAN VALUE

1970

Figure 23. Legend

```
C   OWNER OCCUPIED HOUSING UNITS. AVERAGE VALUE
C  PALOS VERDES SECTOR
C  1000-YARD PERMIT AREA OF L. A. COUNTY COASTAL ZONE


DATA VALUE EXTREMES ARE          0.0      58786.21


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
       ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM       0.0   49698.85  50000.00
  MAXIMUM  49698.85   50000.00  58786.21


PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

              84.54      0.51      14.95


FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1          2          3
          ********************************
           ---------- ██████████ ██████████
           ---------- ██████████ ██████████
  SYMBOLS  ---- ----- ████ █████ ████ █████
           ---------- ██████████ ██████████
           ---------- ██████████ ██████████
          ********************************
  FREQ.          1          1         10
        1   I-- --I    I██ ██I   I██ ██I
        2                        I██ ██I
        3                        I██ ██I
        4                        I██ ██I
        5                        I██ ██I
        6                        I██ ██I
        7                        I██ ██I
        8                        I██ ██I
        9                        I██ ██I
       10                        I██ ██I
```



OWNER OCCUPIED HOUSING-MEAN VALUE

1970

Figure 24. Legend

```
C  POPULATION DENSITY (PER SQUARE MILE)
C  LOS ANGELES - LONG BEACH HARBOR SECTOR
C  1000-YARD PERMIT AREA OF L. A. COUNTY COASTAL ZONE


DATA VALUE EXTREMES ARE          0.0      28313.98


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
       ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM      0.0      134.76    2500.00    5000.00   10000.00   15000.00   20000.00
  MAXIMUM    134.76    2500.00    5000.00   10000.00   15000.00   20000.00   28313.98


PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               0.48       8.35       8.83      17.66      17.66      17.66      29.36


FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL            1          2          3          4          5          6          7
           ========================================================================
           ---------  .........  =========  +++++++++  XXXXXXXXX  @@@@@@@@@  █████████
           ---------  .........  =========  +++++++++  XXXXXXXXX  @@@@@@@@@  █████████
  SYMBOLS  ---- ----  .... ....  ==== ====  ++++ ++++  XXXX XXXX  @@@@ @@@@  ████ ████
           ---------  .........  =========  +++++++++  XXXXXXXXX  @@@@@@@@@  █████████
           ---------  .........  =========  +++++++++  XXXXXXXXX  @@@@@@@@@  █████████
           ========================================================================
  FREQ.           18         11          5          9          4         10          2
        1   I-- --I    I.. ..I    I== ==I    I++ ++I    IXX XXI    I@@ @@I    I██ ██I
        2   I-- --I    I.. ..I    I== ==I    I++ ++I    IXX XXI    I@@ @@I    I██ ██I
        3   I-- --I    I.. ..I    I== ==I    I++ ++I    IXX XXI    I@@ @@I
        4   I-- --I    I.. ..I    I== ==I    I++ ++I    IXX XXI    I@@ @@I
        5   I-- --I    I.. ..I    I== ==I    I++ ++I               I@@ @@I
        6   I-- --I    I.. ..I               I++ ++I               I@@ @@I
        7   I-- --I    I.. ..I               I++ ++I               I@@ @@I
        8   I-- --I    I.. ..I               I++ ++I               I@@ @@I
        9   I-- --I    I.. ..I               I++ ++I               I@@ @@I
       10   I-- --I    I.. ..I                                     I@@ @@I
       11   I-- --I    I.. ..I
       12   I-- --I
       13   I-- --I
       14   I-- --I
       15   I-- --I
       16   I-- --I
       17   I-- --I
       18   I-- --I
```

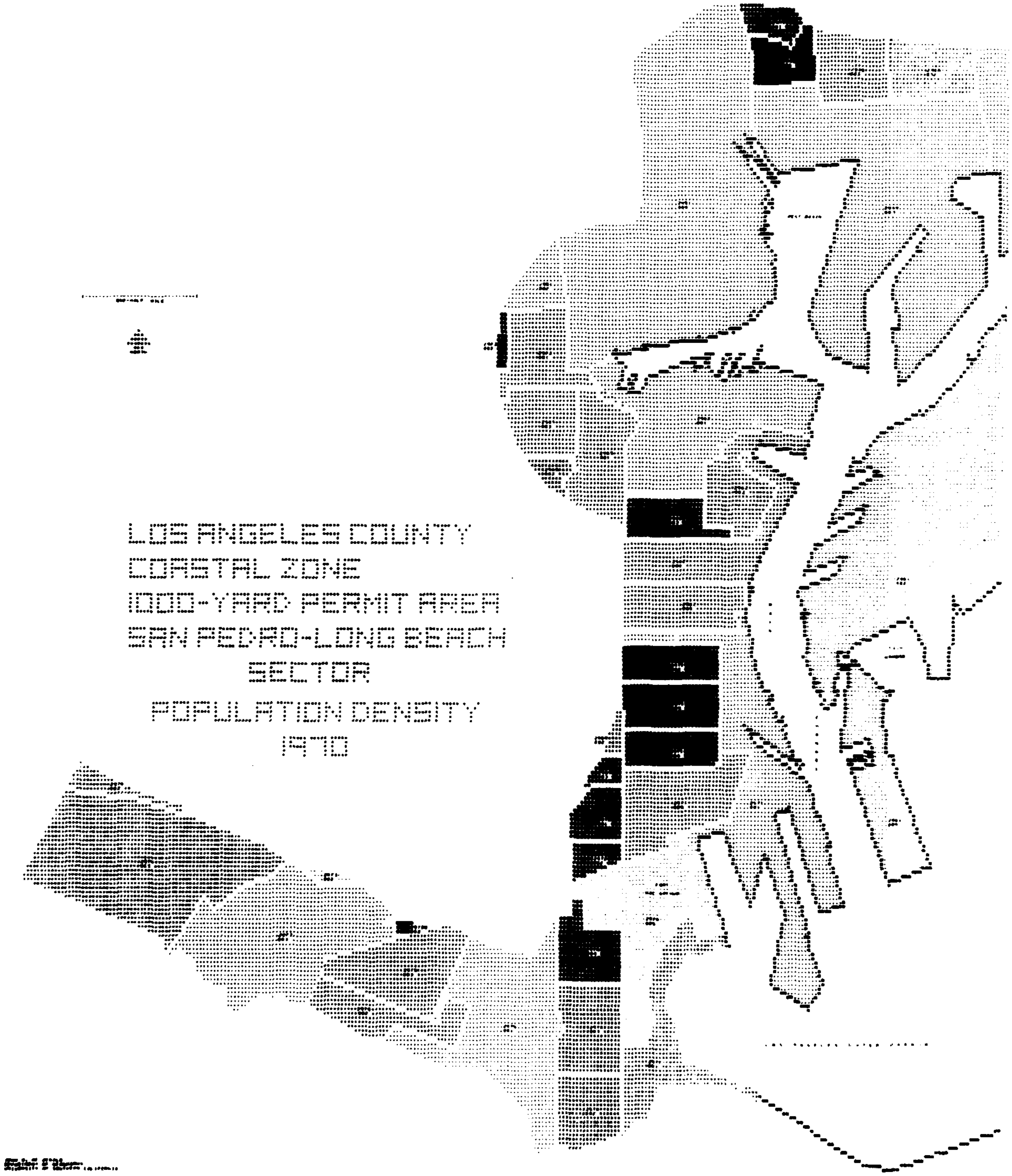
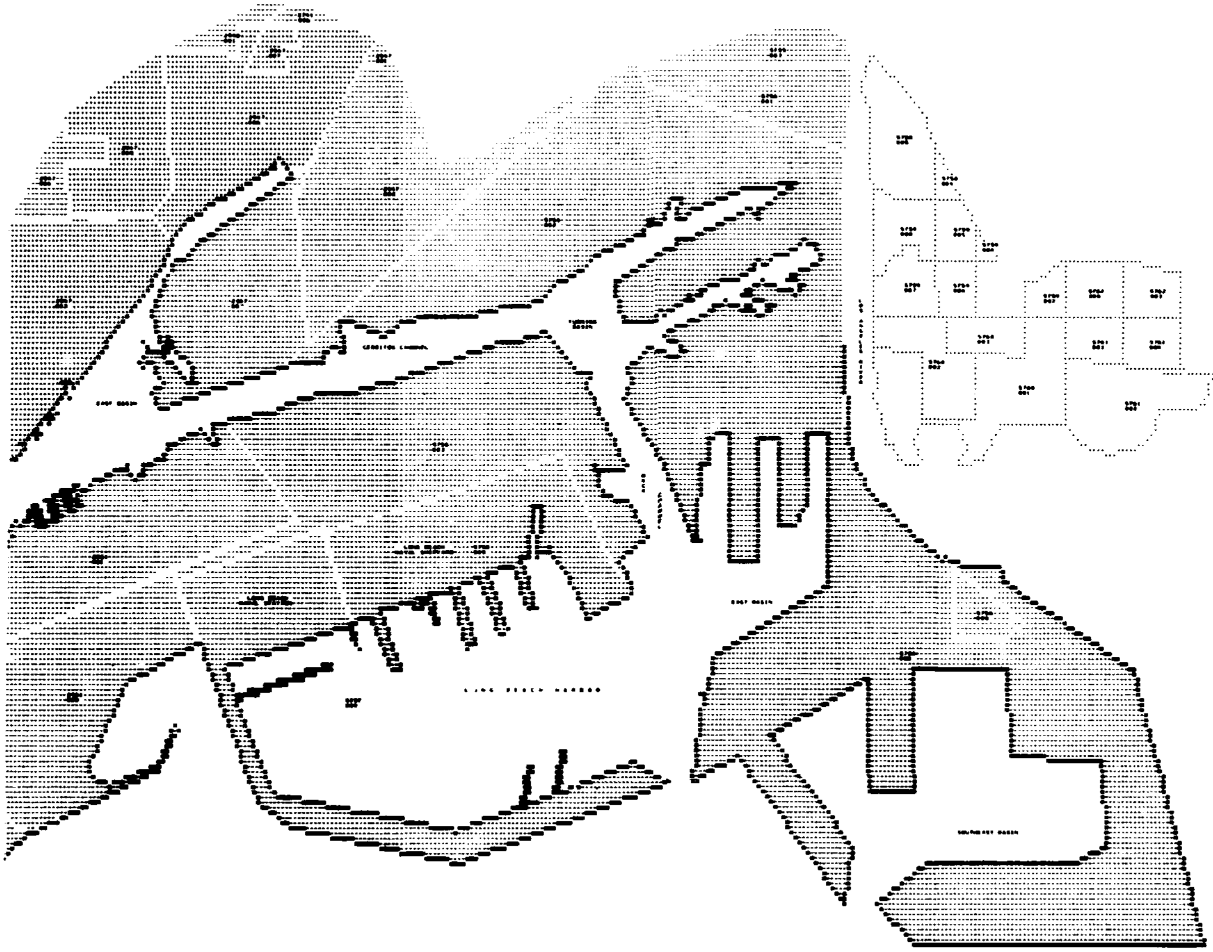

LOS ANGELES COUNTY
COASTAL ZONE
1000-YARD PERMIT AREA
SAN PEDRO-LONG BEACH
SECTOR
POPULATION DENSITY
1970

Figure 25. Legend

```
C  POPULATION DENSITY (PER SQUARE MILE)

C  LOS ANGELES - LONG BEACH HARBOR SECTOR

C  1000-YARD PERMIT AREA OF L. A. COUNTY COASTAL ZONE


DATA VALUE EXTREMES ARE          0.0      28313.98


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM       0.0      134.76   2500.00   5000.00  10000.00  15000.00  20000.00
  MAXIMUM    134.76     2500.00   5000.00  10000.00  15000.00  20000.00  28313.98


PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

              0.48       8.35      8.83     17.66     17.66     17.66     29.36


FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL           1         2         3         4         5         6         7
          ======================================================================
           ---------  .........  =========  +++++++++  XXXXXXXXX  @@@@@@@@@  ■■■■■■■■■
           ---------  .........  =========  +++++++++  XXXXXXXXX  @@@@@@@@@  ■■■■■■■■■
 SYMBOLS   ----  ----  ....  ....  ====  ====  ++++  ++++  XXXX  XXXX  @@@@  @@@@  ■■■■  ■■■■
           ---------  .........  =========  +++++++++  XXXXXXXXX  @@@@@@@@@  ■■■■■■■■■
           ---------  .........  =========  +++++++++  XXXXXXXXX  @@@@@@@@@  ■■■■■■■■■
          ======================================================================
 FREQ.          18        11         5         9         4        10         2
       1   I--  --I  I..  ..I  I==  ==I  I++  ++I  IXX  XXI  I@@  @@I  I■■  ■■I
       2   I--  --I  I..  ..I  I==  ==I  I++  ++I  IXX  XXI  I@@  @@I  I■■  ■■I
       3   I--  --I  I..  ..I  I==  ==I  I++  ++I  IXX  XXI  I@@  @@I
       4   I--  --I  I..  ..I  I==  ==I  I++  ++I  IXX  XXI  I@@  @@I
       5   I--  --I  I..  ..I  I==  ==I  I++  ++I             I@@  @@I
       6   I--  --I  I..  ..I             I++  ++I             I@@  @@I
       7   I--  --I  I..  ..I             I++  ++I             I@@  @@I
       8   I--  --I  I..  ..I             I++  ++I             I@@  @@I
       9   I--  --I  I..  ..I             I++  ++I             I@@  @@I
      10   I--  --I  I..  ..I                                  I@@  @@I
      11   I--  --I  I..  ..I
      12   I--  --I
      13   I--  --I
      14   I--  --I
      15   I--  --I
      16   I--  --I
      17   I--  --I
      18   I--  --I
```



POPULATION DENSITY
1970

Figure 26. Legend

```
C  HOUSING DENSITY (UNITS PER SQUARE MILE)

C  LOS ANGELES - LONG BEACH HARBOR SECTOR

C  1000-YARD PERMIT AREA OF L. A. COUNTY COASTAL ZONE


DATA VALUE EXTREMES ARE          0.0       7603.03


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
       ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM        0.0        34.40    1280.00    2500.00    5000.00
  MAXIMUM      34.40      1280.00    2500.00    5000.00    7603.03

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

                0.45       16.38      16.05      32.88      34.24

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL            1          2          3          4          5
           ==================================================
            ---------  .........  =========  +++++++++  XXXXXXXX
            ---------  .........  =========  +++++++++  XXXXXXXX
  SYMBOLS   ---- ----  .... ....  ==== ====  ++++ ++++  XXXX XXXX
            ---------  .........  =========  +++++++++  XXXXXXXX
            ---------  .........  =========  +++++++++  XXXXXXXX
           ==================================================
  FREQ.           18         13          4         12         12
         1   I-- --I    I.. ..I    I== ==I    I++ ++I    IXX XXI
         2   I-- --I    I.. ..I    I== ==I    I++ ++I    IXX XXI
         3   I-- --I    I.. ..I    I== ==I    I++ ++I    IXX XXI
         4   I-- --I    I.. ..I    I== ==I    I++ ++I    IXX XXI
         5   I-- --I    I.. ..I               I++ ++I    IXX XXI
         6   I-- --I    I.. ..I               I++ ++I    IXX XXI
         7   I-- --I    I.. ..I               I++ ++I    IXX XXI
         8   I-- --I    I.. ..I               I++ ++I    IXX XXI
         9   I-- --I    I.. ..I               I++ ++I    IXX XXI
        10   I-- --I    I.. ..I               I++ ++I    IXX XXI
        11   I-- --I    I.. ..I               I++ ++I    IXX XXI
        12   I-- --I    I.. ..I               I++ ++I    IXX XXI
        13   I-- --I    I.. ..I
        14   I-- --I
        15   I-- --I
        16   I-- --I
        17   I-- --I
        18   I-- --I
```

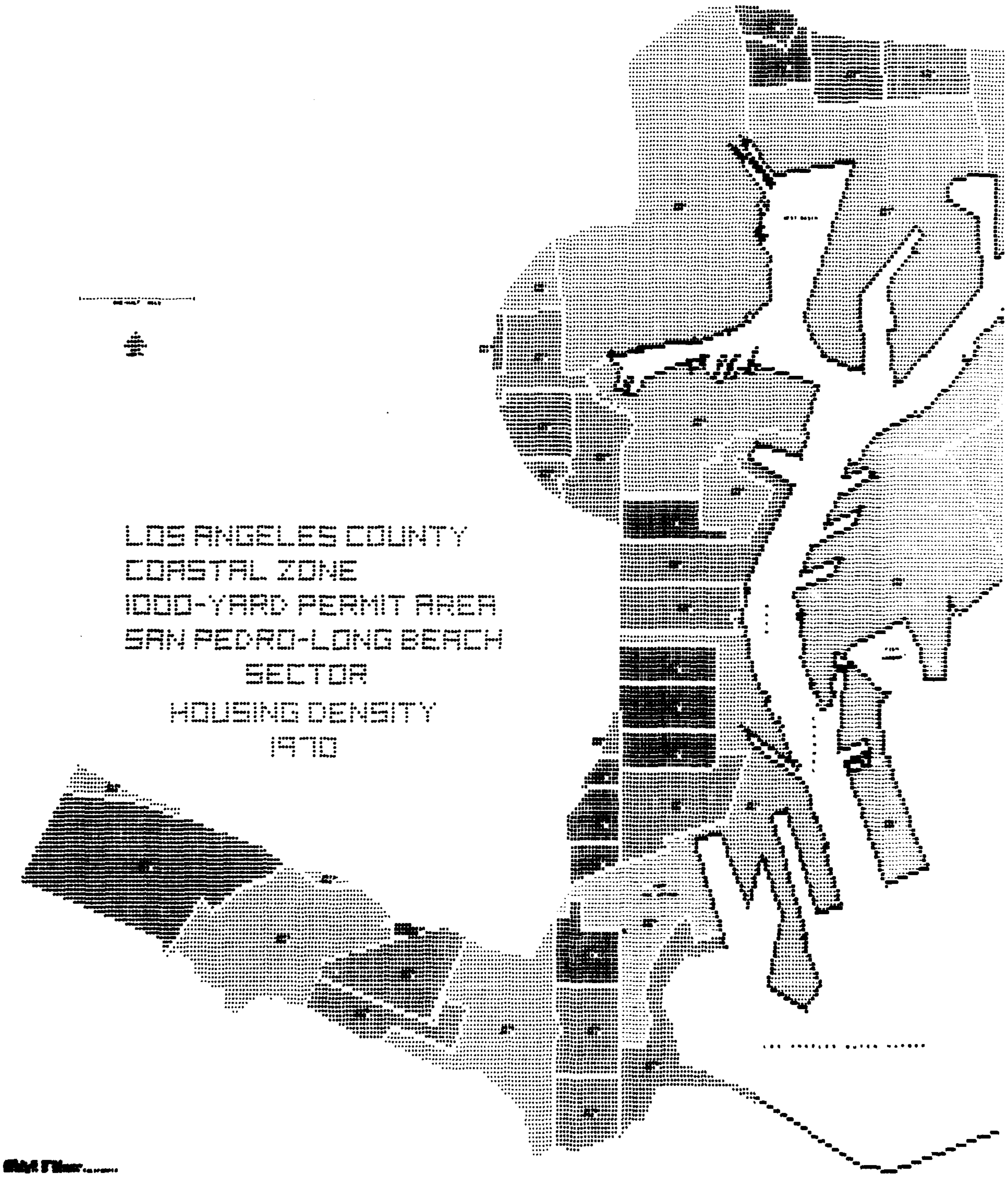
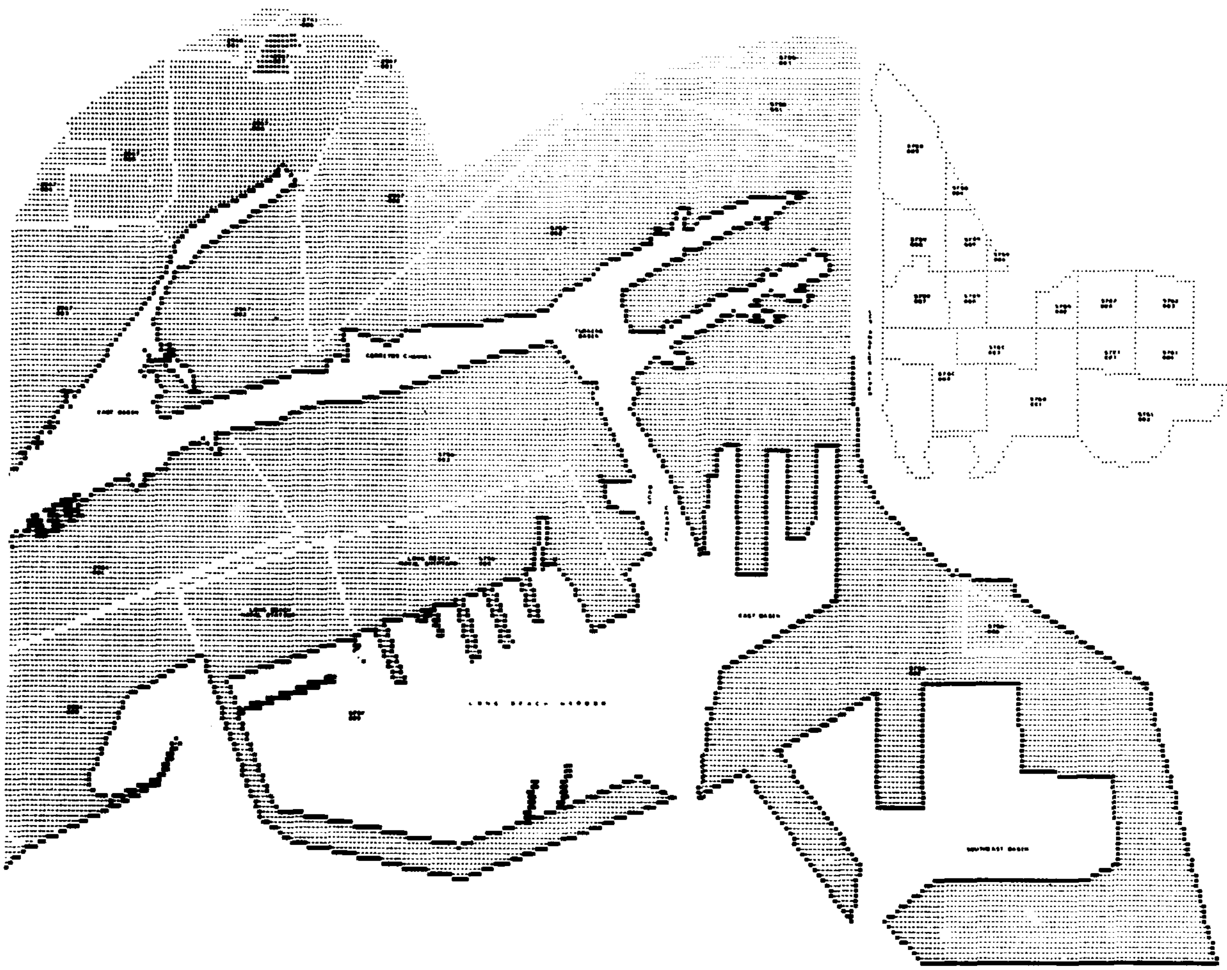

LOS ANGELES COUNTY
COASTAL ZONE
1000-YARD PERMIT AREA
SAN PEDRO-LONG BEACH
SECTOR
HOUSING DENSITY
1970

Figure 27. Legend

```
C  HOUSING DENSITY (UNITS PER SQUARE MILE)
C  LOS ANGELES - LONG BEACH HARBOR SECTOR
C  1000-YARD PERMIT AREA OF L. A. COUNTY COASTAL ZONE


DATA VALUE EXTREMES ARE          0.0       7603.03


ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
       ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM        0.0       34.40   1280.00   2500.00   5000.00
  MAXIMUM      34.40     1280.00   2500.00   5000.00   7603.03

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

                0.45       16.38     16.05     32.88     34.24

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL           1          2         3         4         5
           =================================================
           ---------  .........  =========  +++++++++  XXXXXXXX
           ---------  .........  =========  +++++++++  XXXXXXXX
  SYMBOLS  ---- ----  .... ....  ==== ====  ++++ ++++  XXXX XXXX
           ---------  .........  =========  +++++++++  XXXXXXXX
           ---------  .........  =========  +++++++++  XXXXXXXX
           =================================================
  FREQ.          18         13         4         12        12
        1   I-- --I    I.. ..I    I== ==I   I++ ++I   IXX XXI
        2   I-- --I    I.. ..I    I== ==I   I++ ++I   IXX XXI
        3   I-- --I    I.. ..I    I== ==I   I++ ++I   IXX XXI
        4   I-- --I    I.. ..I    I== ==I   I++ ++I   IXX XXI
        5   I-- --I    I.. ..I              I++ ++I   IXX XXI
        6   I-- --I    I.. ..I              I++ ++I   IXX XXI
        7   I-- --I    I.. ..I              I++ ++I   IXX XXI
        8   I-- --I    I.. ..I              I++ ++I   IXX XXI
        9   I-- --I    I.. ..I              I++ ++I   IXX XXI
       10   I-- --I    I.. ..I              I++ ++I   IXX XXI
       11   I-- --I    I.. ..I              I++ ++I   IXX XXI
       12   I-- --I    I.. ..I              I++ ++I   IXX XXI
       13   I-- --I    I.. ..I
       14   I-- --I
       15   I-- --I
       16   I-- --I
       17   I-- --I
       18   I-- --I
```



OWNER OCCUPIED HOUSING-MEAN VALUE
1970

Figure 28. Legend

C PERCENT OF HOUSING RENTER OCCUPIED

C LOS ANGELES - LONG BEACH HARBOR SECTOR

C 1000-YARD PERMIT AREA OF L. A. COUNTY COASTAL ZONE

DATA VALUE EXTREMES ARE 0.0 0.92

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	0.0	0.04	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
MAXIMUM	0.04	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	0.92

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

4.35	17.39	10.87	10.87	10.87	10.87	10.87	10.87	10.87	2.17

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	-	.	=	0	+	X	H	8	@	■
FREQ.	18	6	0	2	2	3	10	8	9	1

LOS ANGELES COUNTY
COASTAL ZONE
1000-YARD PERMIT AREA
SAN PEDRO-LONG BEACH
SECTOR
HOUSING-PERCENT RENTER OCCUPIED
1970

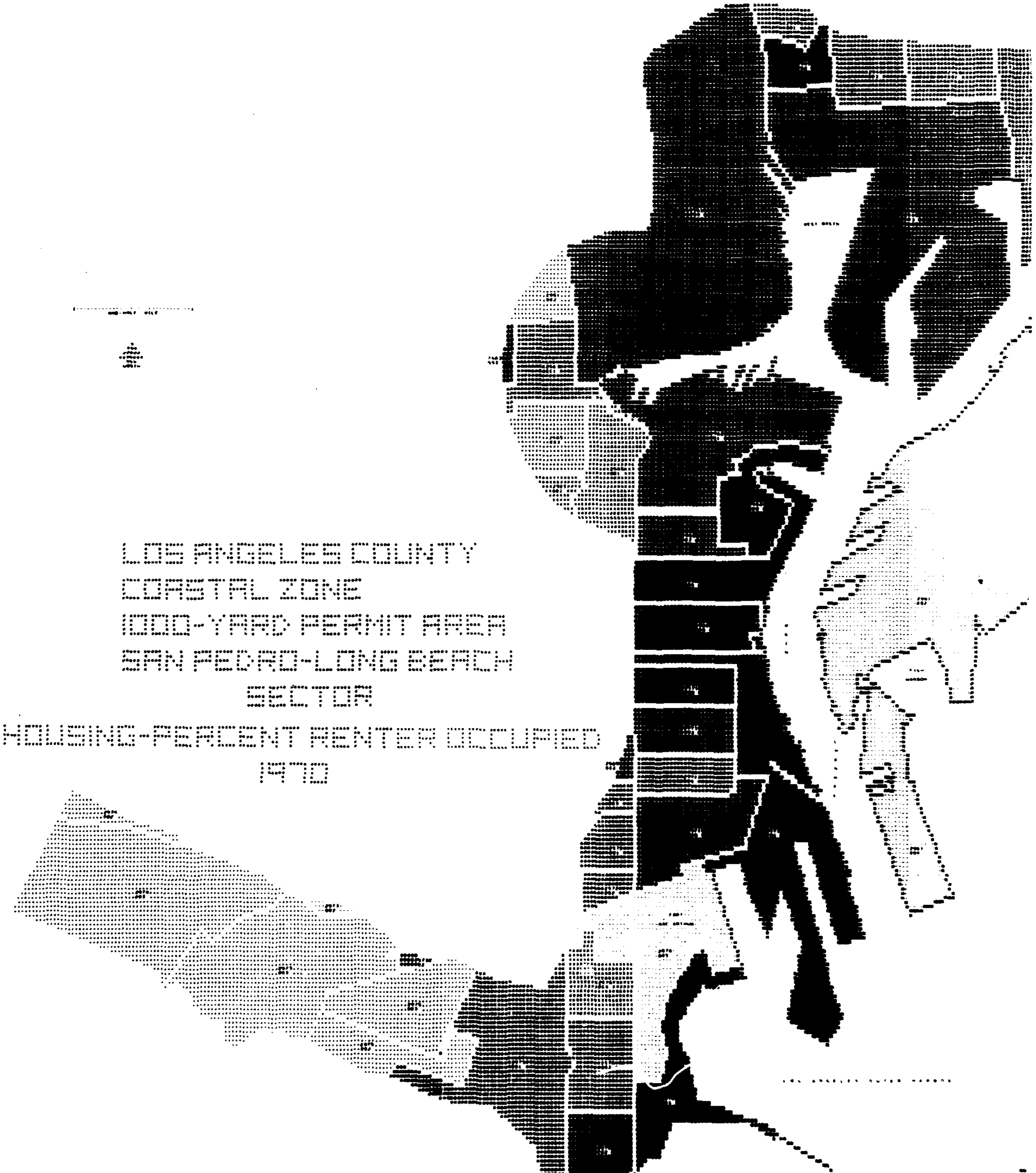


Figure 29. Legend

C PERCENT OF HOUSING RENTER OCCUPIED

C LOS ANGELES - LONG BEACH HARBOR SECTOR

C 1000-YARD PERMIT AREA OF L. A. COUNTY COASTAL ZONE

DATA VALUE EXTREMES ARE 0.0 0.92

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

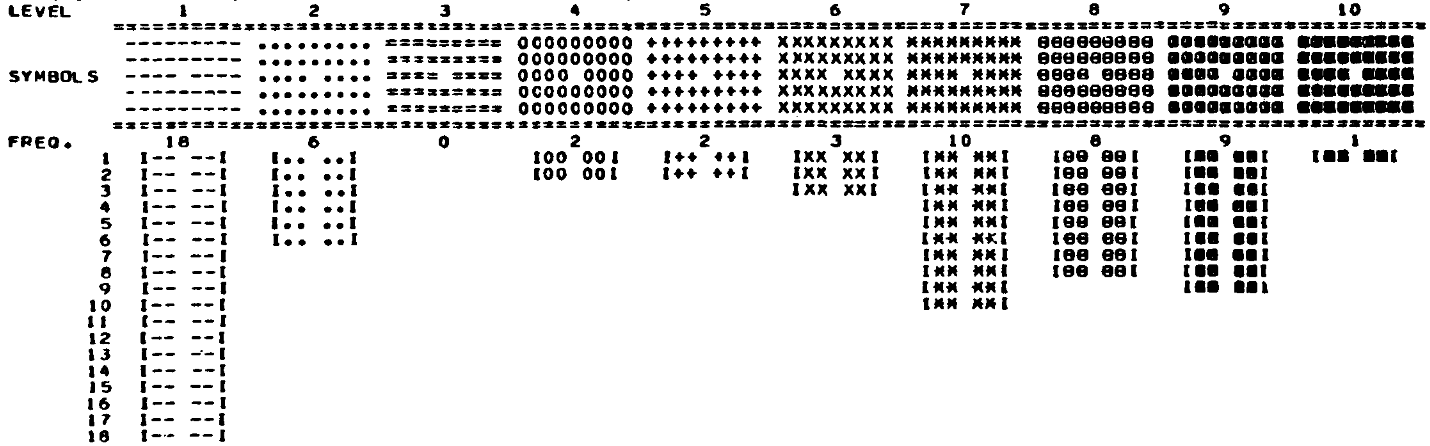
MINIMUM	0.0	0.04	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
MAXIMUM	0.04	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	0.92

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

4.35	17.39	10.87	10.87	10.87	10.87	10.87	10.87	10.87	2.17

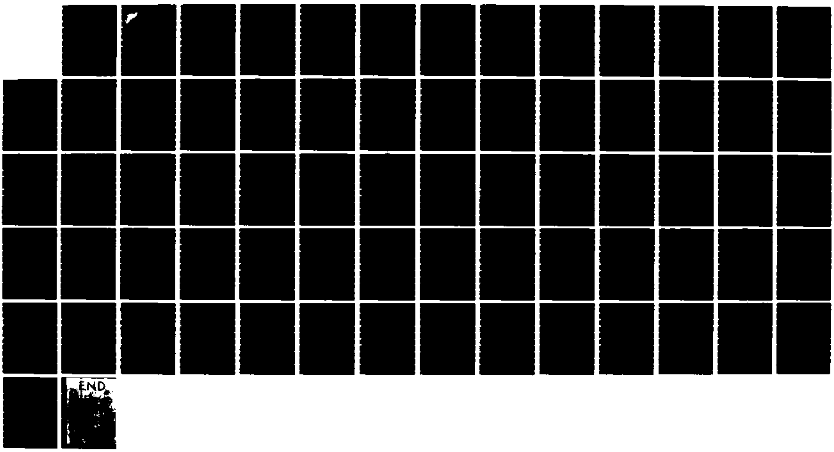
FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

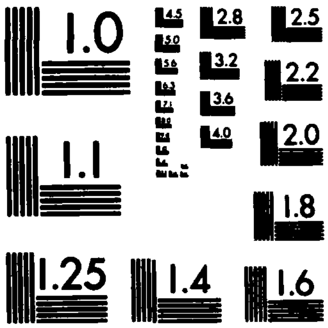
LEVEL	1	2	3	4	5	6	7	8	9	10
FREQ.	18	6	0	2	2	3	10	8	9	1



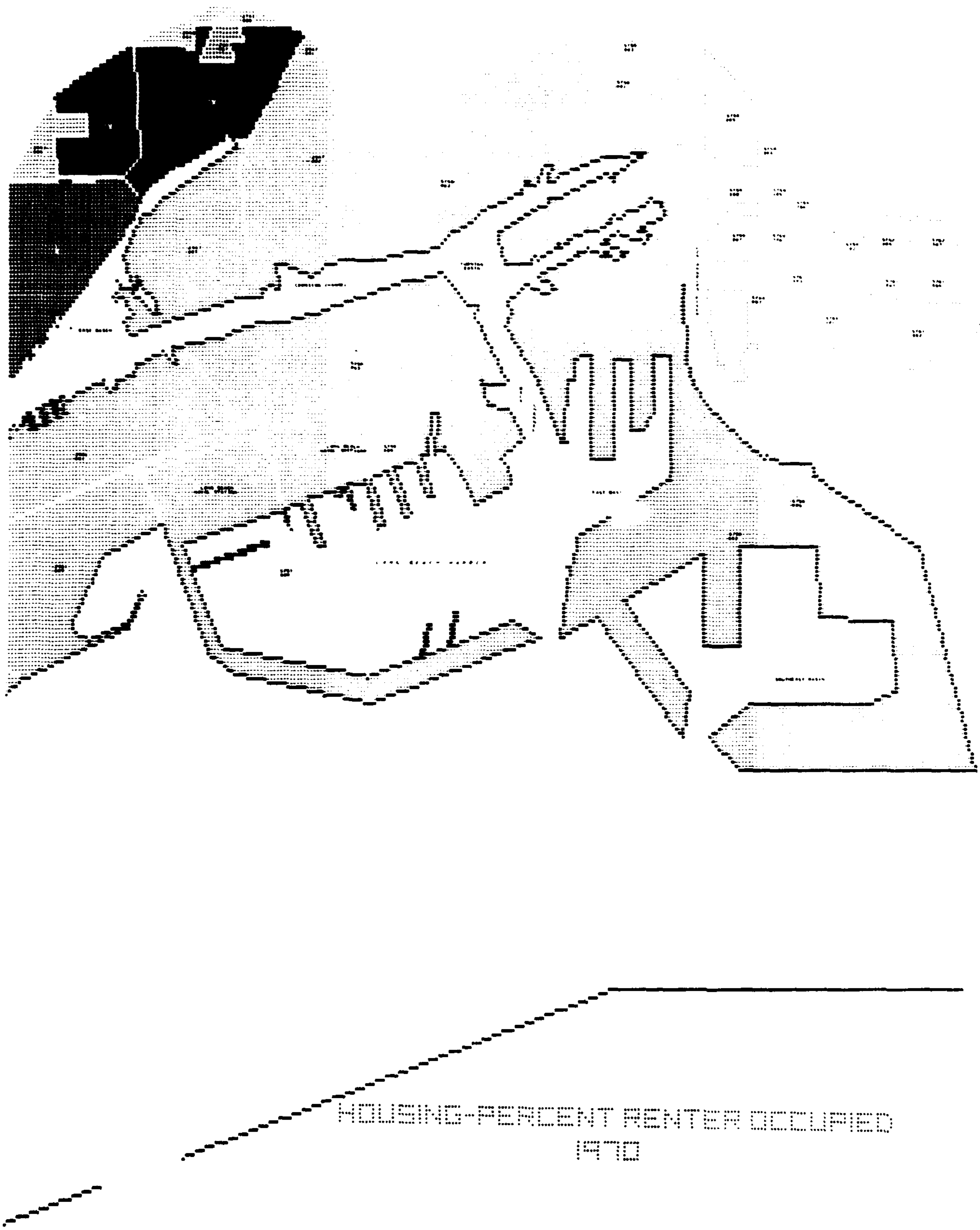
AD-A136 653 ENVIRONMENTAL INVESTIGATIONS AND ANALYSES FOR LOS ANGELES-LONG BEACH HARB..(U) UNIVERSITY OF SOUTHERN CALIFORNIA LOS ANGELES ALLAN HANCOCK F.. DEC 76 8/8

UNCLASSIFIED DACW09-73-C-0112 F/G 8/10 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



HOUSING-PERCENT RENTER OCCUPIED
1970

Appendix A

LITERATURE DEALING WITH PHYSICAL AND BIOLOGICAL ASPECTS OF LOS ANGELES-LONG BEACH HARBOR

APPENDIX A
LITERATURE DEALING WITH PHYSICAL AND BIOLOGICAL ASPECTS OF LOS ANGELES-LONG BEACH HARBOR

Over fifty percent of the literature dealing with the Los Angeles-Long Beach Harbor has appeared since the fifties, at which time the harbor was already severely polluted. Therefore, references to the animal population prior to severe pollution are scattered and can be found in such taxonomical references as McFarland (1966), De Laubenfels (1932) and the reminiscences of Emery and Elsie Chace (1967).

In the years since the initial development of the harbor in 1871, pollution has become an increasing problem. The first complaint was in 1926 concerning damage by sulfides to various installations in the area. Pollution in later years has become a serious problem, the sources being industrial and domestic wastes and storm drains. Reish (1959) illustrated a map of the Los Angeles - Long Beach Harbor giving areas that were then being polluted from various sources. Also listed were monthly air temperature, rainfall, tidal fluctuations and other data pertinent to the harbor. He also analyzed various areas of the harbor as to the degree of pollution not only in his 1959 paper but in his others, which are found listed in the bibliography.

Reish has used various bottom dwelling invertebrates as indicators of the quality of the environment. These include the polychaetes *Podarke pugettensis, Nereis procera, Lumbrineris minima, Dorvillea articulata, Polydora paucibranchiata, Cirriformia luxuriosa, Cossura candida, Tharyx parvus, Chaetozone corona, Capitella capitata, Capitata ambiseta,* and *Pectinaria californiensis,* plus the pelecypods *Chione undatellum, Macoma nasuta,* and *Tellina butloni.* Reish considers *Capitella capitata* a species characteristic of the polluted zones in harbors; *Capitata ambiseta, Pectinaria californiensis, Lumbrineris minima, Cossura candida* as indicators of a healthy bottom. The other species do not seem to fall into such clear-cut categories.

Barnard (1958) found that amphipods and polychaetes were consistently the earliest and most abundantly settled groups to be found in Los Angeles-Long Beach Harbor. The tunicate *Ciona intestinalis* was the only representative from another group that was an early settler. Tubicolous amphipods were most abundant in areas of high turbidity, when favorable oxygen and temperature conditions were present. High turbidity can support a population, not only of tubicolous amphipods but also of other suspension feeders.

In a study of the relationship of oxygen and temperature

to settling of *Hydroides norvegica* (Reish, 1961), a serpulid polychaete, settlement was greatest in years of the warmest temperatures. The same may be said for seasonal settlement. The chance of settling was also coupled with a high circulation of dissolved oxygen. Reish came to the conclusion that if both oxygen and temperature were low, there would be a reduction in settling.

Other studies dealing with seasonal settlement in the harbor are those by Menzies, Mohr and Wakeman, 1964, and Reish, 1961. The first citation deals with wood borers and the second with seasonal settlement of marine organisms in general.

Several studies have dealt directly with the effect of pollution on marine life. Young (1964) studied the effects of the sewer effluent on marine life. The fish analyzed in the study all showed the effects of the pollution in varying degrees. More obvious afflictions were tumors and lesions on various parts of the body.

Reish (1971) produced a report on some basic faunal changes that occurred following an edict by the California Water Quality Control Board, Los Angeles, in 1969 that the discharge of oil refinery wastes in Dominquez Channel be prohibited. This has been the single most important step toward the clean-up of Los Angeles Harbor. In this area of the inner harbor, the water and bottom sediment were essentially devoid of life. Reish (1971) reported a significant increase in the number of species in just a brief period since the oil companies ceased dumping either wastes or oxygen-depleting fractions of discharge.

The bottom sediments of the harbor, according to Reish (1959), consist primarily of black muds possessing a sulfide odor. He found such muds in the majority of the slips and basins and the main channel of Los Angeles Harbor. Sand and shell fragmented bottoms were found only occasionally (Reish, 1959).

In 1971, Dr. Dorothy Soule and Mr. Mikihiko Oguri began an intensive study of the harbor. Some of the results have already been published through the joint efforts of the Allan Hancock Foundation and the Office of Sea Grant at the University of Southern California. Soule and Oguri (1972) published the results of a 24-hour drogue study which showed that the outfall areas had very low water exchange. In 1973, a series of articles were published in one volume that included an analysis of the fish population inside the harbor (Chamberlain, 1973) which was compared with the fish

community outside the harbor (Stephens, Gardiner and Terry, 1973). Schafer and Swan (1973) illustrated a difference in the amino acids of anchovies in comparing those anchovies collected in the harbor with those collected outside the harbor. Brewer (1973) wrote an extensive annotated bibliography on the anchovy. Foxworthy (1973), by introducing a fluorescent dye into the effluents from the cannery, traced the dilution and dispersion of these waters. Juge and Griest (1973) introduced dye into the domestic sewage effluent and analyzed microbial life in the receiving water areas and noted their possible effect on the environment. Smith (1973) analyzed the polychaetes as to species groups and the effect of abiotic factors such as trace and heavy metals and pesticides on worm populations. Pinter (1973) traced the history of the fishing industry on the Pacific Coast and the general problems associated with the effluents. An annotated bibliography was also included.

The most important biological studies dealing with the harbor were those of Reish, Reish and Barnard, Crippen and Reish, Menzies and Mohr, and the data published by those associated with Soule and Oguri. Many of the other reports are state, federal and local agency studies dealing with pollution and water quality in the harbor. The following sections present an annotated bibliography of literature dealing with physical and biological information on the Los Angeles-Long Beach Harbor, and a list of species previously recorded in the published literature from the harbor area.

Special agency reports concerning adjacent waters are listed at the end of the literature survey. These include reports from SCCWRP (Southern California Coastal Water Resources Project) and the California State University Consortium.

Environmental Impact Reports filed with the California Regional Coastal Commissions contain environmental information of varying levels of credibility. Often the consultants supplying the information are not identified in the documents. Since there is no regulation requiring archiving of specimens, no validation of results is possible.

LITERATURE CITED

Abbott, B.C., D.F.Soule, M.Oguri and J.D.Soule. 1973. *In situ* studies of the interface of natural and manmade systems in a metropolitan harbor. Helgoländer wiss. Meeresunters 24:455-464.

Adams, J.R. 1969. Thermal power, aquatic life, and kilowatts on the Pacific coast. Nuclear News 12(9):75-79.

Alabaster, J.S. 1963. The effect of heated effluents on fish. Int. J. Air Water Poll. 7:541-563.

Alabaster, J.S. and A.Swain. 1963. Heated water and fish. Ann. Rept. Challenger Soc. 3(15):39.

Albee, A.L. 1969. Earthquake characteristics and fault activity in southern California. In Engineer. Geol. in southern California. AEG Special Publication.

Algermissen, S.T. 1969. Seismic risk studies of the United States, Proc. of 4th World Conference on Earthquake Engineering, Santiago, Chile.

Allan Hancock Foundation. 1959. Oceanographic survey of the continental shelf area of southern California. Calif. State Water Qual. Contr. Bd., Publ. No. 20. 560 pp.

Allan Hancock Foundation. 1965. Oceanographic and biological survey of the southern California mainland shelf. Calif. State Water Qual. Contr. Bd., Publ. No. 27. 234 pp; Appendix, 446 pp.

Allen, C.R., et al. 1965. Seismicity and geologic structure in the southern California region. Seis. Soc. Amer. Bull. 55(4).

Allen, D.R. 1973a. Subsidence rebound and surface strain associated with oil producing operation, Long Beach, California. In Geology, Seismicity, and Environment Impact. D.E.Moran, et al., eds. AEG Special Publication.

Allen, D.R. 1973b. Environment impact statement: Long Beach tidelands and unit oil and gas operations, Wilmington and East Wilmington oil fields, Los Angeles County, California. A report prepared by the city of Long Beach Department of Oil Properties.

Allen, D.R. and M.N.Mayuga. 1969. The mechanics of compaction and rebound, Wilmington oil field, Long Beach, California. Association Internationale D'Hydrologie Scientifique, Actes du Solloque de Tokyo, Sept. 1969. Affaissement du Sol.

American Petroleum Institute. 1969. Petrochemical evaporation loss from storage tanks. API Bull. 2523.

Anderson, J.M. 1971. Assessment of the effects of pollutants on physiology and behavior. Proc. Roy. Soc. Lond. Bull. 177:307-320.

Anon. Proceedings of the sixth dredging seminar. Texas A & M Univ., Sea Grant Publ. No. TAMU-SG-74-104. 105 pp.

Anon. 1964. The effects of heated effluents on fish. Adv. Water Poll Res. 1:261-292.

Anon. 1971. Harbor dredging presents waste disposal problem. Maritimes 15(4):11-15.

Anon. 1971. Study and report on environmental effects of disposal of dredged material. Commerce Business Daily 14.

Anon. 1972. Bartow maintenance dredging: An environmental' approach. World Dredging and Marine Const. 8(13):54-60.

Anon. Interim report on gross physical and biological effects of overboard spoil disposal, May 1, 1967. Chesapeake Biological Laboratory, Univ. of Maryland, College Park, Md.

Army Engineers. 1974. Dredged material research program. Annual Report 1. AEWES, Vicksburg, Miss.

Army Engineers. 1975. Dredged material reserach program. Annual Report 2. AEWES, Vicksburg, Miss.

Austin, H.M. 1972. Contouring zooplankton as a function of temperature and salinity. N.Y.Sci. Lab. Tech. Rpt. No. 0012.

Ballinger, D.G. and G.D.McKee. 1971. Chemical characterization of bottom sediments. J.Water Poll. Contr. Fed. 43:216-227.

Bamford, E.F. 1921. Social aspects of the fishing industry at Los Angeles Harbor. Thesis, Univ. So. Calif., Los Angeles.

Bancroft, H.H. 1884. History of California. Vol. 1, 1542-1800. In History of the Pacific States of North America, Vol. 13. A.L.Bancroft and Co., San Francisco. 744 pp.

Bandy, O.L. 1958. Dominant molluscan faunas of the San Pedro Basin, California. J. Paleontol. 32:703-714.

Banner, A.H. 1954. Some schizopod crustaceans from the deeper water off California. Allan Hancock Foundation Publ. Occas. Paper 13:1-48.

Banning, P. 1869. Letter to Col. Williamson, p. 482. U.S.Engin. Dept., Report of the Chief of Engineers, Washington, D.C. U.S.Government Printing Office. 650 pp.

Barnard, J.L. 1950. The occurrence of *Chelura terebrans* Philippi in Los Angeles and San Francisco Harbors. Bull. So. Calif. Acad. Sci. 49:90-97.

Barnard, J.L. 1953. On two new amphipod records from Los Angeles Harbor. Bull. So. Calif. Acad. Sci. 52:83-87.

Barnard, J.L. 1954. A new species of *Microjassa* (Amphipoda) from Los Angeles Harbor. Bull. So. Calif. Acad. Sci. 53:127-130.

Barnard, J.L. 1955. The wood boring habits of *Chelura terebrans* Philippi in Los Angeles Harbor. Allan Hancock Fdnt. Essays Nat. Sci., Honor. Capt. Allan Hancock, p. 87-98.

Barnard, J.L. 1958. Amphipod crustaceans as fouling organisms in Los Angeles-Long Beach Harbors, with reference to the influence of seawater turbidity. Calif. Fish and Game 44(2): 161-170.

Barnard, J.L. and R.R.Given. 1961. Morphology and ecology of some sublitorral cumacean Crustacea of southern California. Pac. Natur. 2:153-165.

Barnard, J.L. and D.J.Reish. 1957. First discovery of marine wood-boring copepods. Science 125(3241):236.

Barnard, J.L. and D.J.Reish. 1960. Wood-browsing habits of the harpacticoid copepod *Tisbe gracilis* (T.Scott) in southern California. Pac. Natur. 1(22):9-12.

Barnes, H. 1959. Temperature and life cycle of *Balanus balanoides* (L.). In Marine Boring and Fouling Organisms, D.L. Ray, ed. Univ. of Washington Press, Seattle, Wash. p. 234-245.

Barnes, H. 1963. Oceanography and marine ecology. Ann. Rev., Vol. 1. George Allan and Unwin, Ltd., London. 478 pp.

Barnett, P.R.O. 1971. Some changes in intertidal sand communities due to thermal pollution. Proc. Roy. Soc. London Bull. 177:353-364.

Barrows, A.G. 1973. Earthquakes along the Newport-Inglewood structural zone. Calif. Geol.26(3):60-68.

Basco, D.R., et al. 1974. Assessment of the factors controlling the long-term fate of dredged material deposited on unconfined subaqueous disposal areas. Texas A & M Univ., College Station. Rpt. No. AEWES-CR-D-74-8. 244 pp.

Bascom, W. 1974. The disposal of waste in the ocean. Sci. Amer. 231(2):16-25.

Baslow, M.H. and R.F.Nigrelli. 1964. The effect of thermal acclimation on brain cholinesterase activity of the killifish, *Fundulus heteroclitus*. Zoologica 49:41-51.

Bayne, B.L. 1965. Growth and delay of metamorphosis of the larvae of *Mytilus edulis*. Ophelia 2(1):1-47.

Bayne, B.L. 1971. Oxygen consumption by three species of Lamellibranch mollusc in declining ambient oxygen tension. Comp. Biochem. and Physiol. 40:955-970.

Bayne, B.L. 1973. Physiological changes in *Mytilus edulis* (L.) induced by temperature and nutritive stress. J.Mar. Biol. Assoc. U.K. 53:39-58.

Beecher, J. 1915. History of Los Angeles Harbor. Thesis, Univ. So. Calif., Los Angeles.

Beers, G.D. 1972. The role of dredging in the ecosystem management program proposed for the Los Angeles Harbor. Environmental Engineering and Science Conference, 2nd Annual. Summaries. Univ. of Louisville, pp. 14-16.

Bella, D.A. 1972. Environmental considerations for esturarine dredging operations. Proc. World Dredging Conference IV, pp. 457-482.

Bella, D.A. 1974. Benthal sulfide release in aquatic systems. Oregon State Univ. Corvallis, Dept. of Civil Engineering, W75-00696, 19 pp.

Bellan, G., D.J.Reish and J.P.Foret. 1972. The sublethal effects of a detergent on the reproduction, development, and settlement of the polychaetous annelid, *Capitella capitata*. Mar. Biol. 14(3):183-188.

Berner, L.D. and J.L.Reid, Jr. 1961. On the response to changing temperature of the temperature-limited plankton *Doliolum Denticulatum* Quay and Gaimard, 1835. Limnol. and Oceanogr. 6:205-215.

Biggs, R.B. 1968. Environmental effects of overboard spoil disposal. Amer. Soc. Civil Engin., J.San. Engin. 94:477-487.

Bischoff, J.L. and T.Lung. 1971. Pore fluids of recent marine sediments. J.Sed. Petrol. 41(1008).

Blanton, J. and J.G.Pattullo. 1970. The subsurface boundary between subarctic Pacific water and Pacific equatorial water in the transition zone off southern California. Limnol. and Oceanogr. 15(4):606-614.

Bohlen, W.F. 1974. An investigation of turbidity in estuarine waters. Connecticut Univ., Storrs Inst. of Water Resources. W75-02881, 15 pp.

Bolt, B.A. 1973. Duration of strong ground motion. Proc. of the 5th World Conf. on Earthquake Engineering. Rome, Italy.

Bouldin, D.R. 1968. Models for describing the diffusion of oxygen and other mobile constituents across the mud-water interface. J.Ecol. 56(77).

Boyd, M.B., R.T.Saucier, J.W.Keeley, R.L.Montgomery, P.T.Brown, D.B.Mathis and C.J.Guice. 1972. Disposal of dredge spoil. Tech. Rpt. H-72-8. U.S.Army Engineers Waterways Experiment Station, Vicksburg, Miss.

Bravinder, K.M. 1942. Los Angeles basin earthquake of October 21, 1941, and its effects on certain producing wells in the Dominguez Field, Los Angeles County, California. American Assoc. of Petrol. Geol. Bull. 26:388-399.

Brehmer, M.L., et al. 1967. A study on the effects of dredging and dredge spoil disposal on the marine environment. Spec. Sci. Rpt. No. 8, Virginia Inst. of Marine Sciences.

Brenko, M.H. and A.Calabrese. 1969. The combined effects of salinity and temperature on the larvae of the mussel *Mytilus edulis*. Mar. Biol. 4(3):224-226.

Brett, J.R. 1956. Some principles in the thermal requirements of fishes. Quart. Rev. of Biol. 31(2):75-87.

Brett, J.R. 1969. Temperature and fish. Ches. Sci.10(3):275-276.

Brewer, G.D. 1973. Annotated bibliography on the northern anchovy, *Engraulis mordax* Girard. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part II, Biological Investigations. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. 237 p.

Brewer, G.D. 1974. Preliminary observations on the lower minimum temperature requirements of the northern anchovy. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 3. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 21-43.

Brewer, G.D. 1975. The biology and fishery of the northern anchovy in San Pedro Bay. Potential impact of proposed dredging and landfill. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 8. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 23-44.

Brewer, G.D. 1976. Resuspended sediment elutriate studies on the northern anchovy. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 11. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 15-32.

Brook, A.J. and A.L.Baker. 1972. Chlorination at power plants: Impact on phytoplankton productivity. Science 176:1414-1415.

Brookhout, C.G. and J.D.Costlow. 1969. Temperature and meroplankton. Ches. Sci. 19(3-4):252-255.

Bruland, K.W. 1974. History of metal pollution in southern California coastal zones. Env. Sci. and Tech. 8(5): 425-435.

Cable, C.C. 1969. Optimum dredging and disposal practices in estuaries. Am. Soc. Civil Engin. 95(HY1):103-114.

Cairns, J., Jr. 1956. Effects of increased temperatures on aquatic organisms. Indust. Wastes 1(14):150.

Cairns, J., Jr. 1967. Suspended solids standards for the protection of aquatic organisms. Proc. 22nd Ind. Waste Conf., Purdue Univ, Ext. Ser. 129(16).

Cairns, J., Jr. 1971. Thermal pollution: A cause for concern. J. Water Poll. Contr. Fed. 43(1):55-66.

Cairns, J., Jr. and K.L.Dickson. 1971. A simple method for the biological assessment of the effects of waste discharges on aquatic bottom-dwelling organisms. J. Water Poll. Contr. Fed. 43(755).

California Dept. Fish and Game. 1967. From the bibliography of various authors: Prediction of thermal energy distribution in streams and reservoirs. Rpt. to the Calif. Fish and Game (June), WRB, Inc.

California Dept. of Water Resources. 1958. Sea-water intrusion in California. Bull. 63.

California Dept. of Water Resources. 1967. Earthquake damage to hydraulic structures in California. Bull. 116-3.

California Dept. of Water Resources. 1971. Land use in California. Bull. 176.

California Dept. of Water Resources. 1973. Hydrologic data. 1972, southern California. Bull. 130-72, Vol. V.

California Division of Mines and Geology. 1962-1969. Geologic map of California, 1:250,000. Los Angeles and Santa Ana.

California Division of Mines and Geology. 1973. State of California preliminary fault and geologic map. Preliminary Rpt. 13.

California Division of Mines and Geology. 1973. Urban geology: Master plan for California. Bull. 198.

California Division of Mines and Geology. 1974. A review of the geological and earthquake history of the Newport-Inglewood structural zone. Southern California. Spec. Rpt. 114.

California Regional Water Quality Control Board. 1971. Interim water quality control plan for the Santa Clara River and Los Angeles River basins (basins 4 and 4b). Calif. Reg. Water Res. Contr. Bd., L.A.

California Resources Agency. 1972. State water resources control board water quality control plan for ocean waters of California. July 6, 1972.

California State Assembly. 1949. Report to the interim fact finding committee on water pollution.

California State Coastal Zone Conservation Commission. 1975. Coastal Plan.

California, State of, Department of Fish and Game. 1951. Bottom condition in Los Angeles-Long Beach Harbors.

California, State of, Department of Public Health. Progress report, Los Angeles River pollution committee for the period May, 1948-April, 1949.

California, State of, Department of Public Health. Progress report, Los Angeles River Pollution committee for the period May, 1949-April.1950.

California, State of, Department of Public Health, Bureau of Sanitary Engineering. 1951. Los Angeles-Long Beach pollution survey.

California, State of, Department of Public Health, Bureau of Sanitary Engineering. 1952. Los Angeles-Long Beach Harbor pollution. Los Angeles Regional Water Pollution Control Board. 43 p.

California, State of, Division of Water Resources. 1952. Report on the investigation of Los Angeles River.

California, State of, Los Angeles Regional Water Pollution Control Board. 1952. Second progress report on the water pollution control program in the Los Angeles region. Staff report, December.

California, State of, Los Angeles Regional Water Pollution Control Board. 1955. A study of the use of coastal waters of the Pacific Ocean and adjacent beaches within the boundaries of the county of Los Angeles. Staff report, March.

California, State of, Los Angeles Regional Water Pollution Control Board. 1961. Report on investigation of fish kills in Los Angeles Harbor (June 21, 1961-Oct. 5, 1961). Staff report, November.

California, State of, Los Angeles Regional Water Quality Control Board. 1954 through 1967. Staff reports to Board.

California, State of, Resources Agency. 1969. Review of information pertinent to Los Angeles-Long Beach Harbors and Dominguez Channel. Staff report to the Los Angeles Regional Water Quality Control Board.

California State Secretary of Resources. 1975. Guidelines for implementation of the California Environmental Quality Act of 1970. Revision record for Register 75, No. 1-22.

California State Water Resources Control Board. 1972. Water Quality Control plan for control of temperature in the coastal and interstate waters and enclosed bays and estuaries of California.

California State Water Resources Control Board. 1972. Water Quality Control plan for ocean waters of California. 13 p.

California State Water Resources Control Board. 1972. Guidelines for technical reports and monitoring programs.

Cannon, Ray. 1967. How to fish the Pacific Coast. Lane Books. 160 p.

Carlisle, J.G., Jr. 1969. Results of a six-year trawl study in an area of heavy waste discharge: Santa Monica Bay, California. Calif. Fish and Game 55:26-46.

Carroll, D. 1959. Ion exchange in clays and other minerals. Geol. Soc. Amer. Bull. 70(749).

Chace, E.P. and E.M.Chace. 1967. Conchological reminiscences. Recollections of Emery P. Chace and Elsie M. Chace, with the help of notebooks. San Diego. 38 p.

Chamberlain, D.W. 1973. Results of 14 benthic trawls conducted in the outer Los Angeles-Long Beach Harbors, California, May 24, 1972. <u>In</u> Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part II, Biological Investigations. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. 237 p.

Chamberlain, D.W. 1974. A checklist of fishes from Los Angeles-Long Beach Harbors. <u>In</u> Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 4. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 43-78.

Chamberlain, D.W. 1975. The role of fish cannery waste in the ecosystem. <u>In</u> Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 8. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 1-22.

Chamberlain, D.W. 1976. Effects of Los Angeles Harbor sediment elutriate on the California killifish, *Fundulus parvipinnis*, and white croaker, *Genyonemus lineatus*. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 11. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 33-48.

Chen, K.Y. and J.C.S.Lu. 1974. Sediment compositions in Los Angeles-Long Beach Harbors and San Pedro Basin. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 7. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 1-177.

Chen, K.Y. and C.C.Wang. 1974. Feasibility study of treatment of dredge spoils. Rpt. to Board of Harbor Commissioners, City of Los Angeles. (unpublished). 28 p.

Chen, K.Y. and C.C.Wang. 1974. The water quality effects and treatments of returned effluents from a diked disposal area. Rpt. to Board of Harbor Commissioners, City of Los Angeles (unpublished). 81 p.

Chen, K.Y. and C.C.Wang. 1976. Water quality evaluation of dredged material disposal from Los Angeles Harbor. In Marine Studies of San Pedro Bay, California. Part 11. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 155-236.

Chen, K.Y. and T.F.Yen. 1972. Models for the fate of metals in sediment. Preprint, Division Water, Air and Waste Chem., Amer. Chem. Soc., 164th Nat'l. Mtg. p. 165.

Chen, K.Y., C.S.Young, T.K.Jan, and N.Rohatgi. 1975. Suspended and dissolved trace metals in wastewater effluent. J. Water Poll. Contr. Fed. 46:2663-2675.

Clark, J.R. 1969. Thermal pollution and aquatic life. Sci. Amer. 220(3):18-27.

Cole, L.C. 1969. Thermal pollution. Bioscience 19(11):989-992.

Committee on Interior and Insular Affairs, United States Senate. 1974. Deepwater port policy issues. National fuels and energy policy study. No. 93-42(92-77).

Cornell, C.A. 1968. Engineering seismic risk analysis. Bull. Seis. Soc. Amer. 58.

Costlow, J.D., Jr., C.G.Bookhout, and R.Monroe. 1962. Salinity-temperature effects on the larval development of the crab *Panopeus herbstii* Milne-Edwards, raised in the laboratory. Physiol. Zool. 35:79-93.

Council on Environmental Quality. 1970. Ocean dumping - a national policy. 45 p. October, 1970.

Council of Environmental Quality. 1971. Toxic substances.

Council on Environmental Quality. 1971. Ocean dumping - a national policy.

Crippen, R.W. and D.J.Reish. 1969. An ecological study of the polychaetous annelids associated with fouling material in Los Angeles Harbor with particular reference to pollution. Bull. So. Calif. Acad. Sci. 68:169-186.

Crisp, D.J. 1957. Effects of low temperature on the breeding of marine animals. Nature (London) 179(4570).

Cronin, L.E., G.Gunter, and S.H.Hopkins. 1971. Effects of engineering activities on coastal ecology. Report of Office, Chief of Engineers. U.S.Army.

Crooke, S.J. 1969. Result of a live bait sampling study on the northern anchovy and its fishery. Calif. Fish and Game Bull. 147:90-102.

Crosby, L.G. and D.L.Durham. 1975. Los Angeles and Long Beach Harbors model study: Observations of ship mooring and movement. Tech. Rpt. H-75-4, Rpt. 2. U.S.Army Engineers Waterways Experiment Station, Vicksburg, Miss.

Cross, F.A., T.W.Duke and J.N.Willis. 1970. Biogeochemistry of trace elements in a coastal plain estuary: distribution of manganese, iron, and zinc in sediments, water, and polychaetous worms. Ches. Sci. 11(4):221-234.

Crown, W.J. 1941. Wilmington oil field: Summary of operations. California Division of Oil and Gas. Vol. 26.

Dehlinger, P., et al. 1974. Investigations on concentrations, distributions, and fates of heavy metal wastes in parts of Long Island Sound. Conn. Univ., Groton, Marine Sciences Inst., NOAA-74121601. 166 p.

de Goeij, J.J.M., V.P.Guinn, D.R.Young, and A.J.Mearns. 1973. Activation analysis trace element studies of Dover sole liver and marine sediments. In Comparative Studies of Food and Environmental Contamination, Finland.

de Laubenfels, M.W. 1932. The marine and freshwater sponges of California. Proc. U.S.N.M. 81(2927):1-140.

DeVoss, D.W. 1949. A comparative analysis of organizational and functional aspects of the Los Angeles and Long Beach port administration. Thesis, Univ. So. Calif., Los Angeles.

Dominguez Channel Users' Group. 1965. Report on hydrogen sulfide study of Dominguez Channel. December.

Dominguez, R.F. 1971. Muddy aspects of water quality affecting dredging. World Dredging and Marine Construction 7(14): 21-23.

Doudoroff, P. 1938. Reactions of marine fishes to temperature gradients. Biol. Bull. 75(3):494-509.

Dow, R.I. 1964. A comparison among selected marine species of an association between seawater temperature and relative abundance. J. du Conseil 28(4):425-431.

Dow, R.I. 1969. Cyclic and geographic trends in seawater temperature and abundance of American lobster. Science 164 (3883):1060-1063.

Drost, H.W. 1969. Allowable thermal pollution limits - a physico-chemical approach. Chesapeake Science 10(3):281-288.

Duke, T.W., J.N.Willis, and D.A.Wolfe. 1968. A technique for studying the exchange of trace elements between estuarine sediments and water. Limnol. and Oceanogr. 13(541).

Eichholtz, G.G., T.F.Craft, and A.N.Galli. 1967. Trace element fractionation by suspended matter in water. Geochim. Cosmochim. Acta 31:737.

Emerson, R.R. 1974. Preliminary investigations of the effects of resuspended sediment on two species of benthic polychaetes from Los Angeles Harbor. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 3. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 97-110.

Emerson, R.R. 1976. Bioassay and heavy metal uptake investigations of resuspended sediment on two species of polychaetous annelids. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 11. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 69-90.

Emery, K.O. 1960. The Sea off Southern California. John Wiley and Sons, Inc., New York. 366 p.

Engineering Science, Inc. 1971. Report on ecosystem management alternatives.

Environmental Protection Agency. 1972. Compilation of air pollutant emission factors. AP-42. Superintendent of Documents. FS2.300:AP-42.

Environmental Protection Agency. 1973. Ocean dumping: Final regulations and criteria. Federal Register 38(198):2861-2862.

Environmental Protection Agency. 1975. Preparation of environmental impact statements: Final regulations. Federal Register 40-72.

Eppley, R.A. 1966. Earthquake history of the United States, Part 2. U.S.Dept. of Commerce, Washington, D.C.

Fagerstrom, T. and A.Zerneloz. 1971. Formation of methylmercury from pure mercuric sulfide in aerobic organic sediment. Water Research (Pergammon Press). 5(121).

Fay, R.C. and J.K.Johnson. 1971. Observations on the distribution and ecology of the littoral ascidians of the mainland coast of southern California. Bull. So. Calif. Acad. Sci. 70(3):114-124.

Fay, R.C., E.D.Michael, J.A.Vallee and G.B.Anderson. 1972. Southern California's deteriorating marine environment. Center for California Public Affairs, Claremont, Cal.

Feth, J.H. 1973. Water facts and figures for planners and managers. Geol. Survey Circular 601.

Fitch, J.E. 1963. The enigma of a hitch-hiking snail. Leaflets in Malacology 1(21):131-133.

Fitch, J.E. 1973. The longnose puffer, *Sphoeroides lobatus* (Steindacher) added to the marine fauna of California. Bull. So. Calif. Acad. Sci. 72(3):163.

Fitch, J.E. and R.J.Lavenberg. 1971. Marine Food and Game Fishes of California. Univ. Calif. Press, Calif. Natl. Hist. Guide 28. 179 p.

Folger, D.W. 1969. Characteristics of estuarine sediments of the United States (unpublished). Rpt. to the Federal Water Pollution Control Administration, Washington, D.C.

Fowler, S.W. and L.F.Small. 1971. Effects of temperature and size on molting of Euphausiid crustaceans. Mar. Biol. 11(11):45-51.

Foxworthy, J.E. 1973. Working report on the dilution of cannery wastes discharges into the Los Angeles Harbor. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part II, Biological Investigations. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 65-78.

Frame, R.G. 1957. A review of water flooding in the Wilmington oil field: Summary of operations. California Division of Oil and Gas 43(1).

Galloway, J.M. 1972. Man's alteration of the natural geochemical cycle of selected trace metals. Ph.D. Dissertation, Univ. of Calif., San Diego.

General Dynamics. 1971. Potential environmental effects of an offshore submerged nuclear power plant. Water Poll. Cont. Res. Series, Environmental Protection Agency, Water Quality Office.

Ginsburg, R.N. and H.A.Lowenstam. 1958. The influence of marine bottom communities on the depositional environment of sediments. J. of Geol. 66:310-319.

Gleason, D. 1958. The Islands and Ports of California. Devin-Adair Co., New York. 201 p.

Godcharles, M.F. 1971. A study of the effects of a commercial hydraulic clam dredge on benthic communities in estuarine areas. Florida Dept. of Natural Resources, St. Petersburg Marine Research Labs, Tech. Ser. 64. 60 p.

Graham, D. 1972. Trace metals in intertidal molluscs of California. Veliger 14(4):365-372.

Grant, U.s. 1954. Subsidence of the Wilmington oil field, California. California Division of Mines and Geol. Bull. 170.

Grassle, J.F. and J.P.Grassle. 1974. Opportunistic life histories and genetic systems in marine benthic polychaetes. J. Mar. Res. 32:253-284.

Green, R.H. 1974. Multivariate niche analysis with temporally varying environmental factors. Ecology 55(1):73-83.

Greensfelder, R.W. 1972. Crustal movement investigations in California: their history, data, and significance. CDMG Special Publ. No. 37.

Greensfelder, R.W. 1974. Maximum credible rock acceleration from earthquakes in California. Calif. Div. Mines and Geol. Map Sheet 23.

Grigg, R.W. and R.S.Kiwala. 1970. Some ecological effects of discharged wastes on marine life. Calif. Fish and Game 56(3):145-155.

Grissinger, E.H. and L.L.McDowell. 1970. Sediment in relation to water quality. Water Resources Bull. 6(7).

Gross, M.G., et al. 1971. Survey of marine waste deposits, New York metropolitan region. Stoneybrook Marine Science Research Center, State Univ. of New York.

Guinn, V.P., M.DiCasa, J.J.M.deGoeij, and D.R.Young. 1975. Neutron activation analysis studies of marine biological species and related marine sediments. In Proc. of the 2nd Int'l. Conf. on Nuclear Methods in Environmental Research.

Gunnerson, C.G. and K.O.Emery. 1962. Suspended sediment and plankton over San Pedro Basin, California. Limnol. and Oceanogr. 7(1):14-20.

Gunter, G. 1957. Temperature. In Treatise on Marine Ecology and Paleo-Ecology. J.Hedgepeth, ed.

Gustafson, J.F. 1972. Beneficial effects of dredging turbidity. World Dredging and Marine Construction 8(13):44-45, 47-48, 50-52, 72.

Hadley, D. and D.Straughan. 1974. Tolerance of *Littorina planaxis* and *L. scutulata* to temperature changes (Mollusca, Gastropoda). In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 3. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 78-96.

Hakenjos, C.B. 1970. Pollution control and dredging. Dredging Seminar, Proceedings. Sea Grant Publ. No. 7-113, 6 pp.

Hann, R.W. 1971. Water quality and the dredging industry. Sea Grant Publ. No. 71-109, pp. 66-85.

Harbors Environmental Projects. 1976. Biotic Environment. In Port of Long Beach Master Environmental Setting.

Hard, C.G. 1972. Dredging disposal. Water Spectrum 4(1):16-21.

Harding, T.P. 1973. Newport-Inglewood trend, California - an example of wrenching style of deformation. Amer. Assoc. Petr. Geol. Bull. 57(1).

Harrison, J.E. 1974. Identification of objectionable environmental conditions and issues associated with confined disposal areas. Arthur D. Little, Inc., Cambridge, Mass. AEWES-CR-D-74-4. 212 p.

Harrison, W. 1967. Environmental effects of dredging and spoil deposition. Proc. World Dredging Conf. p. 535-559.

Hartman, O.H. 1939. Polychaetous annelids. Part I. Aphroditidae to Pisionidae. New species of polychaetous annelids from southern California. Allan Hancock Pacific Exped. 7:170.

Hartman, O.H. 1944. Polychaetous annelids. Part V. Eunicea. Allan Hancock Pacific Exped. 10:1-236.

Hartman, O.H. 1955. Quantitative survey of the benthos of San Pedro Basin, southern California. Part I. Preliminary results. Allan Hancock Pacific Exped. 19:1-185.

Hartman, O.H. 1966. Quantitative survey of the benthos of San Pedro Basin, southern California. Part II. Preliminary results. Allan Hancock Pacific Exped. 19:187-456.

Hartman, O.H. 1968. Atlas of the errantiate polychaetous annelids from California. Allan Hancock Foundation, Univ. So. Calif. 828 p.

Hartman, O.H. 1969. Atlas of the sedentariate polychaetous annelids from California. Allan Hancock Foundation, Univ. So. Calif. 812 p.

Hedgepeth, J.W. 1962. In Between Pacific Tides. E.Ricketts and J.Calvin, eds. Stanford Univ. Press. 516 p.

Hedgepeth, J.W. and J.Gonoi. 1969. Aspects of potential effects of thermal alteration on marine and estuarine benthos. In Biological Aspects of Thermal Pollution. Drenkel and Parker, eds. Vanderbilt Univ., p. 80-188.

Heinle, D.R. 1969. Temperature and zooplankton. Chesapeake Sci. 10(3-4):186-209.

Hendricks, T.J., and J.M.Harding. 1974. The dispersion and possible biological uptake of ammonia in a wastefield, Point Loma, May, 1972. Southern Calif. Coastal Water Res. Project. 11 p.

Hendricks, J.J., and D.R.Young. 1974. Modeling the fates of metals in ocean-discharged wastewaters. SCCWRP TM 208.

Herald, E.S. 1949. A key to the pipefishes of the Pacific American coasts with descriptions of new genera and species. Allan Hancock Pacific Exped. 9:51-64.

Herbick, J.B. 1974. Proceedings of the 6th dredging seminar. Texas A & M Univ., College Station, Center for Dredging Studies. TAMU-56-74-104. 107 pp.

Hermann, R.F.G. and J.G.Carlisle. 1970. The California marine fish catch for 1968 and historical review 1966-1968. Calif. Fish and Game Bull. 149:1-70.

Hileman, J.A., C.R.Allen, and J.M.Nordquist. 1973. Seismicity of the southern California region. 1932 to 1972. Calif. Inst. ot Tech. Publ.

Hill, C.L. and C.A.Kofoid. 1927. Marine borers and their relation to marine construction on the Pacific Coast. (Final Report to the San Francisco Bay Marine Piling Committee). San Francisco. 357 pp.

Hill, H.R. and P.D.Tompkins. 1954. Common sea shells of the Los Angeles County coast. Los Angeles County Museum, Sci. Ser. No. 16, Zool. Pub. No. 7. 48 p.

Hill, L.R. 1974. A seasonal environmental study of the polychaetous annelids within the Long Beach Naval Station and Shipyard, Long Beach, California. Master's Thesis, Calif. State Univ., Long Beach. 97 pp.

Hill, L.R. and D.J.Reish. 1975. Seasonal o-currence and distribution of benthic and fouling species of polychaetes in Long Beach Naval Station and Shipyard, California. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 8. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 57-74.

Hinton, S. 1969. Seashore Life of Southern California. Univ. Calif. Press, Calif. Natl. Hist. Guide 29. 181 p.

Hoak, R.D. 1961. The thermal pollution problem. J.Water Poll. Contr. Fed. 33(12):1267-1276.

Hoffmaster, B.N. 1972. Vertical movement in the Long Beach Harbor district. An annual report to the Long Beach Board of Harbor Commissioners.

Holliday, B.W. 1973. Shell dredging and environmental impact statement: Ocean mining symposium. San Pedro, Calif. World Dredging Assoc.

Holt, R.F. 1969. Run-off and sediment and nutrient sources. Water Res. R.Center Bull. 13(35).

Holt, R.F., et al. 1970. Chemistry of sediment in water. In Agricultural Practices and Water Quality. Iowa State Univ. Press, Ames, Iowa.

Hom, W., R.W.Risebrough, A.Soutar, and D.R.Young. 1974. Deposition of DDE and PCB in dated sediments of the Santa Barbara basin. Science 184:1197-1199.

Hood, D.W., T.W.Duke, and B.Stevenson. 1960. Measurement of toxicity of organic wastes to marine organisms. J. Water Poll. Contr. Fed. 32(9):982-993.

Horne, R.A., et al. 1871. The marine disposal of sewage sludge and dredge spoil in the waters of the New York bight. Woods Hole Oceanog. Inst., Woods Hole, Mass.

Horowitz, A. 1970. The distribution of Pb, Ag, Sn, Te, and Zn in the sediments on active oceanic ridges. Marine Geol. 9(241).

Horvath, C. 1951. A study of the Teredinidae of the Los Angeles-Long Beach Harbor. Thesis, Univ. So. Calif., L.A. 145 p.

Horvath, C. and R.J.Menzies. 1952. Resistance to species of marine borers of woods, foreign and domestic, treated and untreated, which have been proposed for marine installations. Marine Borer Conf., Port Hueneme, Ca. Rpt. Q1-Q3.

Housner, G.W. 1965. Intensity of earthquake ground shaking near the causative fault. Proc. of the 3rd World Conf. on Earthquake Engineering, New Zealand.

Houston, J.R. 1975. Preliminary report, Long Beach Harbor. Numerical analysis of harbor oscillations. Waterways Experiment Station, U.S.Army Corps of Engineers.

Huang, J.C., et al. 1974. Pollution potential of aquatic sediments. Missouri Univ., Rolla, Department of Chemistry. W-75-04150. 96 p.

Hunter, S.N. and J.A.McLaughlin. 1958. Poisonous tides. Scientific American (August):92-98.

Hurley, D.E. 1956. Bathypelagic and other Hyperiidea from California waters. Allan Hancock Foundation, Univ. So. Calif., Occas. Pap. 18:25.

Hwang, L., I.Yang, D.Divoky, and A.Yuen. 1972. A study of wave and ship behavior at Long Beach Harbor with application to a modern container ship. Tetra Tech. Rpt. TC-182.

Hyman, L.H. 1953. The polyclad flatworms of the Pacific Coast of North America. Bull. Amer. Mus. Nat. Hist. 100:269-392.

Iida, K. 1970. The generation of tsunamis and the local mechanism of earthquakes in tsunamis in the Pacific Ocean. Proc. of the Int'l. Symp. on Tsunamis and Tsunami Research, Honolulu, Hawaii.

Ingle, R.M. 1952. Studies on the effect of dredging operation upon fish and shellfish. Tech. Ser. No. 5, Florida State Board of Conservation, St. Petersburg, Fla.

Jenkins, S.H. 1969. Advances in water pollution research. Inst. Assoc. on Water Poll. Res. Proc. 4th Int'l. Conf. held in Prague, 1961. Pergammon Press, 936 pp.

Jennings, C.W. and R.G.Strand. 1969. Los Angeles sheet geologic map of California. Calif. Div. of Mines and Geology.

Jensen, S. and A.Zernelov. 1969. Biological methylation of mercury in aquatic organisms. Nature 233(753).

Jones, A.S.G. 1972. Partial geochemical study of shallow marine sediment. Mar. Biol. 12(313).

Jones, G.F. 1965. The macrofauna communities of the southern California mainland shelf (abstr.). Bull. Am. Malac. Un. 32:57-58. AMU Annual Report.

Jones, G.F. 1969. The benthic macrofauna of the mainland shelf of southern California. Allan Hancock Fdtn., Univ. So. Calif. Monogr. Mar. Biol. 4:219.

Jones, J.H. 1971. General circulation and water characteristics in the southern California bight. SCCWRP TR 101.

Juge, D.M. and G.Griest. 1973. The roles of microbial activity in the harbor ecosystem. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part II, Biological Investigations. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 29-64.

Juge, D.M. and G.Griest. 1975. A modification of BOD method for use in the marine environment. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 8. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 45-56.

Kallberg, K.T. and C.A.Cornell. 1969. Seismic risk in southern California. Report R69-31, Dept. of Civil Engineering, Mass. Inst. Tech.

Kaplan, E.H., et al. 1973. Some effects of dredging on populations of macrobenthic organisms. Hofstra Univ., Hempstead New York, Dept. of Biology, NOAA-74052202-11. 37 pp.

Keeley, J.W. and R.M.Engler. 1974. Discussion of regulatory criteria for ocean disposal and dredged materials: Elutriate test rationale and implementation guidelines. Misc. Paper D-74-14, U.S.Army Engineers Waterways Experiment Station, Vicksburg, Miss.

Keith, D.E. 1969. Aspects of feeding in *Caprella californica* (Stimpson) and *Caprella equilibra* Say (Amphipoda). Crustaceana 16(2):119-124.

Kennedy Engineers. 1960. Biochemical study of Dominguez Channel. San Francisco.

Kennedy, G.L. 1975. Paleontologic record of areas adjacent to the Los Angeles-Long Beach Harbors, Los Angeles County, California. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 9. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. 119 p.

Kenny, R. 1969. The effects of temperature, salinity and substrate on the distribution of *Clymenella torquata* (Leidy), polychaeta. Ecology 50(4):624-631.

Kenny, R. 1969. Temperature tolerance of the polychaete worms *Diopatra cupree* and *Clymenella torquata*. Mar. Biol. 4(3): 219-223.

Kim, C.H. 1969. Hydrodynamic forces and moments for heaving, swaying, and rolling cylinders on water of finite depth. J.Ship Research.

Kinimel, B.L. and O.T.Long. 1970. Factors influencing orthophosphate concentration decline in the water of laboratory mud-water systems. Texas Journal of Science 21(439).

Kinne, O. 1963. The effects of temperature and salinity on marine and brackish water animals. I. Temperature. Oceanogr. Mar. Biol. Ann. Rev. 1:301-340.

Kinne, O. 1963. The effects of temperature and salinity on marine and brackish water animals. II. Salinity and temperature-salinity combinations. Oceanogr. Mar. Biol. Ann. Rev. 2:281-339.

Kinne, O. 1970. Marine Ecology. I. Environmental factors. Part I. Wiley-Interscience, New York. 681 pp.

Klashman, L.M. and J.S.Farlow. 1971. Review of the federal water quality administration estuarine study findings. J. Water Poll. Contr. Fed. 43(5):739-745.

Klontz, G.W., and R.A.Bendele. 1973. Histopathological analysis of fin erosion in southern California marine fishes. Southern California Coastal Water Res. Project. 8 p.

Kong, R.W. 1972. Air pollution emissions from railroads and marine vessels in Los Angeles County. Air Poll. Contr. District Engineering Div. Rpt.

Kong, R.W. 1974. Supplement No. 3 for computations of air pollution factors. Environmental Protection Agency AP-42.

Koshi, E., M.V.M.Desai, and A.K.Ganguly. 1969. Interactions of metallic ions with humic acids from a marine sediment. Curr. Sci. 38(582).

Kovach, R.L. and C.B.Archambeau. 1972. Source mechanisms for Wilmington oil field, Calif. Subsidence earthquakes, M.S. Subsidence Library, Dept. of Oil Properties, City of Long Beach.

Kramer, D. and J.R.Zweifel. 1970. Growth of anchovy larvae (*Engraulis mordax* Girard) in the laboratory as influenced by temperature. Calif. Mar. Res. Comm., CalCOFI 14:84-87.

Krankel, P.A. and F.L.Parker. 1969. Biological aspects of thermal pollution. Vanderbilt Univ. Press, Portland, Ore. 407 p.

Laberge, R.H. 1959. Thermal discharges. Water Dewage Wks. 106 (12):536-540.

Lance, J.R. 1961. A distributional list of southern California opisthobranchs. Veliger 4:64-68.

Largen, M.S. 1967. The influence of water temperature upon the life of the dog-whelk *Thais lapillus* (Gastropoda: Prosobranchia). J. Anim. Ecol. 36(1):207-214.

Larson, L.C. 1956. Pollution of Los Angeles and Long Beach Harbors. Proc. Amer. Soc. Civ. Eng. 82(891):1-10.

Laverty, B.R. and P.J.West. 1971. Cooling water resources and power generation. Amer. Soc. Civ. Eng., Nat'l. Water Res. Conf., Phoenix, Arizona.

Leathem, W. 1973. Effect of spoil disposal on benthic invertebrates. Marine Poll. Bull. 4(8):122-125.

Lee, C.F. 1974. Literature review on research study for the development of dredged material disposal criteria. U.S. Army Corps of Engineers, WES Report No. AEWES-CR-D-74-1. 170 pp.

Lee, G.F.1970. Factors affecting the transfer of materials between water and sediments. Water Res. Center, Univ. Wis.

Leeds, D.J. 1973. The design earthquake, in geology, seismicity, and environmental impact. D.E.Moran, ed. AEG Spec. Publ.

Leopold, L.B., et al. 1971. A procedure for evaluating environment impact. Geological Survey Circ. 645. U.S.Dept. of the Interior, Washington, D.C.

Leypoldt, H. 1939. Currents in Los Angeles Harbor and vicinity. Proc. U.S. Naval Inst. 65:685-694.

Long Beach Chamber of Commerce. 1975. Demographic and industrial comparison: Long Beach/Los Angeles County, California. May.

Long Beach City Council. 1974. Resolution No. C-21599. (Planning).

Long Beach, City of, Port of Long Beach. Available facilities and statement of commerce. Fiscal year 1967-1968.

Long Beach, City of, Port of Long Beach. 1968. Harbor highlights.

Long Beach City Planning Department. 1975. Statistics on Long Beach population and housing. January.

Long Beach City Planning Department. 1975. Population and growth in Long Beach: A white paper for public discussion. Long Beach, Calif. June.

Long Beach City Planning Department. 1975. Housing element. Long Beach, Calif.

Long Beach City Planning Department. 1975. Scenic routes element. General Plan Program.

Long Beach Department of City Planning 1975. Environmental data base guidelines. (Planning)

Long Beach Economic Development Corporation. 1975. Economic impact of the westside industrial area, Long Beach, Calif. September.

Long Beach Public Library. Unpublished list of historical information: Historical markers in the Long Beach area.

Los Angeles, City of, Board of Harbor Commissioners. 1968. Port of Los Angeles Report. 28 p. See also 1969-1971.

Los Angeles, City of, Department of Public Works, Bureau of Sanitation. Sanitary survey of Los Angeles Harbor. Dec. 1955-July, 1956; August 1956-Feb., 1957.

Los Angeles County Department of Regional Planning. 1975. Quarterly Bull. No. 128: 1970 and 1975 Housing Unit Types, Los Angeles County Statistical Areas.

Los Angeles Department of Regional Planning. 1975. Quarterly Bulletin, Population and Housing by Statistical Areas.

Los Angeles County Air Pollution Control District. 1972. Air pollutant emissions from railroads and marine vessels in Los Angeles County.

Los Angeles County Air Pollution Control District. 1974. Hydrocarbon emissions for storage - refining and marketing.

Los Angeles County Air Pollution Control District. 1974. Air quality and meteorology - 1974 annual report.

Los Angeles County Air Pollution Control District. 1975. Tank losses summary sheet.

Los Angeles, County of, Chief Administrative Officer. 1961. Water pollution in Los Angeles County - Dominguez Channel and Los Angeles Harbor. A memorandum report to the Board of Supervisors. March.

Los Angeles, County of, Department of County Engineer, County Sanitation Districts, and Flood Control District. 1967. Disposal of wastes into the Pacific Ocean, Los Angeles-Long Beach Harbor area and Dominguez Channel. Sept.

Los Angeles, County of, Flood Control District. 1968. Biennial report on hydrologic data. Seasons of 1965-1967. Sept.

Los Angeles, County of, Sanitation District. 1966. Dominguez Channel study.

Los Angeles Harbor Board of Commissioners. Annual station reports on commodities, tonnage values.

Los Angeles Harbor Department Environmental Staff. 1973. Final environmental impact report. Continental Oil Company Petroleum Marine Terminal Revisions for Los Angeles Harbor Department. 57 pp.

Los Angeles Harbor Department Environmental Staff. 1974. Draft environmental impact report. Western LNG Terminal Company, Berth 308, Los Angeles Harbor. Vol. I, Section I (Project Description); Section II (Environmental Setting). 467 pp.

Los Angeles Harbor Department Environmental Staff. 1974. Final environmental impact report. Al Larson Boat Shop, Terminal Island, Calif. 77 pp., Addendum.

Los Angeles Harbor Department Environmental Staff. 1975. Final environmental impact report. Addition to San Pedro Terminal General American Transportation Corporation. (GATX) 87 pp.

Los Angeles Harbor Department Environmental Staff. 1975. Draft environmental impact report. Phillips Petroleum Company, San Pedro Marine Terminal. 31 pp.

Los Angeles Harbor Department Environmental Staff. 1975. Draft environmental impact report. Standard Oil Company of California. San Pedro Marine Terminal.

Los Angeles Harbor Department Environmental Staff. 1975. Paktank Pacific Company Oil storage terminal. Draft EIR.

Los Angeles Harbor Department Environmental Staff. 1975. Final environmental impact report. Maintenance dredging for Los Angeles Harbor. 203 pp.

Los Angeles Harbor Department Environmental Staff. 1975. Final environmental impact report. Union Oil Company of California. Crude oil storage capacity addition, outer harbor station. 83 pp.

Los Angeles Harbor Department Environmental Staff. 1975. Draft environmental impact report. Matson Terminal, Berth 206. 151 pp.

Los Angeles-Long Beach Harbor Pollution Control Committee. 1955. Report for 1954.

Los Angeles Regional Water Pollution Control Board. 1952. Los Angeles-Long Beach Harbor pollution survey. 43 pp.

MacGinitie, G.E. and N.M.MacGinitie. 1968. Natural History of Marine Animals. McGraw-Hill, Inc. New York. 523 pp.

Mallory, C.W. 1974. Containment area facility concepts for dredged material separation, drying, and rehandling. Hittman Assoc., Inc., Columbia, Md. Rpt. No. HIT-576 AEWES-CR-D-74-6, 259 p.

Maloney, N.J. and K.-M.Chan. 1974. Hydrography of harbors, lagoons, and sloughs. In A Summary of Knowledge of the Southern California Coastal Zone and Offshore Areas. Vol. I, Physical Environment. M.D.Dailey, B.Hill, and N.Lansing, eds. Southern Calif. Ocean Studies Consortium, Contract No. 08550-CT4-1. 66 p.

Manheim, F.T. 1970. The diffusion of ions in unconsolidated sediments. Earth and Planet Sci. Letters 9(307).

Marachi, N.D. and S.J.Dixon. 1972. A method of evaluation of seismicity. Proc. of the Conf. on Microzonation for Safer Construction, Seattle, Wash.

Marine Biological Consultants. 1975. Environment and soil sampling for the Port of Long Beach. Interim Report No. 3.

Markowski, S. 1959. The cooling water of power stations: A new factor in the environment of marine and freshwater invertebrates. J.Animal Ecol. 28:243-258.

Markowski, S. 1960. Observations on the response of some benthonic organisms to power station cooling. J.Animal Ecol. 29:349-357.

Markowski, S. 1962. Faunistic and ecological investigations in Cavendish Rock, Barrow-in-Furness. J. Animal Ecol. 31:43-51.

Martino, P.A. and J.M.Marchello. 1968. Using waste heat for fish farming. Ocean Industry April:36-39.

Martner, S.T. 1948. The Dominguez Hills, California, earthquake of June 18, 1944. Seis. Soc. Amer. Bull. 38:105-119.

Masch, F. 1968. Shell dredging - a factor in estuarine sedimentation. Proc. Spec. Conf. on Coastal Engineering, N.Y.Amer. Soc. Civ. Eng.

Matson, C.H. 1948. Building a World Gateway. Pacific Era Publ., Los Angeles. 255 p.

Maurer, D., et al. 1974. Effect of spoil disposal on benthic communities near the mouth of Delaware Bay. Lewis College of Marine Studies, DEL-SG-4-74. 230 p.

May, E.B. 1974. Effects on water quality when dredging a polluted harbor using confined spoil disposal. Alabama Marine Resources Lab., Dauphin Island, NOAA-74092318-1. 9 p.

Mayuga, M.N. 1970. Geology and development of California's giant: Wilmington Field. In Geology and Giant Petroleum Fields. Mem. 14, Amer. Assoc. Petro. Geol.:158-184.

McAnally, W.H. 1975. Los Angeles and Long Beach Harbors model study. Report 5. Tidal verification and base circulation tests. U.S.Army Corps of Engineers Waterways Experiment Station, Vicksburg, Miss.

McConaugha, J.R. 1976. Toxicity and heavy metals in three species of Crustacea from Los Angeles Harbor sediments. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 11. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 49-68.

McDermott, D.J., T.C.Heesen, and D.R.Young. 1974. DDT in bottom sediments around five southern California outfall systems. SCCWRP TM 217.

McFarland, F.M 1966. Studies of opisthobranchiate molluscs of the Pacific coast of North America. Mem. Calif. Acad. Sci. 6:1-546.

McGovern, E. 1930. The growth of Los Angeles and Long Beach Harbors and the unification project (commerce). Thesis, Univ. So. Calif., Los Angeles.

McKee, G.D., L.P.Parish, C.R.Hirth, K.M.Mackenthun, and L.E. Keup. 1970. Sediment-water nutrient relationships. Water and Sewage Works 117(203).

McKee, J.E. 1967. Parameters of marine pollution - an overall evaluation. In T.A.Olson and F.J.Burgess, eds. Publications in Marine Ecology. New York, Interscience Publ. p. 259-266.

McLean, J.H. 1969. Marine shells of southern California. Los Angeles Co. Museum, Sci. Ser. No. 24, Zool. Publ. No. 11. 104 p.

McLeese, D.W. 1956. Effects of temperature, salinity and oxygen on the survival of the American lobster. J.Fish. Res. Bd. Canada 13(2):247-272.

McMaster, R.L. 1967. Compactness variability of estuarine sediments: An in-site study. In Estuaries. G.H.Lauff, ed. AAAS, p. 261-267.

McQual, H.W. 1951. History of Los Angeles Harbor. In First Conference on Coastal Engineering. Long Beach, Calif. p. 259-270.

Mearns, A.J. 1973. Coastal fish and fisheries. In Proceedings of the conference of government representatives on discharges to the Pacific ocean from municipal wastewater treatment facilities. July 12-13, 1973, San Francisco. p. 23-33. SCCWRP Contribution 14.

Mearns, A.J. 1974. Southern California inshore demersal fishes: Diversity, distribution, and disease as responses to environmental quality. CalCOFI Rpt. 17. SCCWRP Contrib. 7.

Mearns, A.J. and M.J.Allen. 1973. Checklist of inshore demersal fishes from southern and central California. So. Calif. Coast. Wat. Res. Proj. 10 p.

Mearns, A.J., M.J.Allen, and M.Sherwood. 1973. An otter trawl survey off the Palos Verdes Peninsula and Santa Catalina Island, May-June, 1972. So. Calif. Coast. Wat. Res. Proj. 21 p.

Mearns, A.J., M.J.Allen, and M.J.Sherwood. 1973. An otter trawl survey of the central Orange County coast. SCCWRP TM 201.

Mearns, A.J., M.J.Allen, and M.J.Sherwood. 1974. An otter trawl survey of Santa Monica Bay, May-June, 1972. So. Calif. Coast. Wat. Res. Proj. 24 p.

Mearns, A.J., M.J.Allen, M.J.Sherwood, and R.Gammon. 1973. An otter trawl survey off the Palos Verdes Peninsula and Santa Catalina Island, November-December, 1972. So. Calif. Coast. Wat. Res. Proj. 25 p.

Mearns, A.J. and C.S.Greene, eds. 1974. A comparative survey of three areas of heavy waste discharge. SCCWRP TM 215.

Mearns, A.J. and P.L.Haaker. 1973. Identifying and coding color anomalies in flatfishes. SCCWRP TM 200.

Mearns, A.J. and L. Harris. 1975. Age, length, and weight relationships in southern California populations of Dover sole. SCCWRP TM 219.

Mearns, A.J. and M.J.Sherwood. 1974. Environmental aspects of fin erosion and tumors in southern California Dover sole. Trans. Amer. Fish. Soc. 103:799-810. SCCWRP Contr. 9.

Mearns, A.J. and L.G.Smith. 1974. Benthic oceanography and the distribution of bottom fish off Los Angeles. SCCWRP Contribution 31.

Mearns, A.J. and H.H.Stubbs. 1974. Comparison of otter trawls used in southern California coastal surveys. So. Calif. Coast. Wat. Res. Proj. 15 p.

Mearns, A.J. and L.S.Word. 1975. Hydrographic and microbiological survey of Santa Monica Basin, winter and summer, 1974. SCCWRP TM 218.

Mendell, G.H. 1871. In United States Engineering Department Report to the Chief of Engineers. p. 942, Appendix W-10.

Mendell. G.H. 1873. In United States Engineering Department Report to the Chief of Engineers. p. 1129, Appendix Z-1.

Mendell, G.H. 1874. In United States Engineering Department Report to the Chief of Engineers. p. 122, Appendix EE-Z.

Mendell, G.H. 1875. In United States Engineering Department Report to the Chief of Engineers. p. 1121, Appendix F-1.

Mendell. G.H. 1877. In United States Engineering Department Report to the Chief of Engineers. p. 120.

Mendell, G.H. 1878. In United States Engineering Department Report to the Chief of Engineers. p. 1291, Appendix H-HZ.

Menzies, R.H. 1951. A new genus and new species of aseliate isopod, *Caecijaera horvathi* from Los Angeles-Long Beach Harbor. Am. Mus. Nov., No. 1542. 7 p.

Menzies, R.J. 1957. The marine borer family Limnoridae (Crustacea, Isopoda). Part I: Northern and Central America: Systematics, distribution and ecology. Bull. Mar. Sci. Gulf and Caribbean 7(2):101-200.

Menzies, R.J. 1958. The distribution of wood-boring *Limnoria* in California. Proc. Calif. Acad. Sci. 29(7):267-272.

Menzies, R.J., J.Mohr and C.M.Wakeman. 1964. The seasonal settlement of wood-borers in Los Angeles-Long Beach Harbors. Wassman J. Biol. 21(2):97-210.

Meredith, D.L. 1973. Nuclear power plant siting: A handbook for the layman. Marine Advisory Service, Sea Grant, Univ. of Rhode Island, Mar. Bull. 6, Kingston, Rhode Id. 32 p.

Merriman, D. 1970. The calefaction of a river. Sci. Amer. 222 (5):42-52.

Messersmith, J.D., J.L.Baxter, and P.M.Roedel. 1969. The anchovy resources of the California current region off California and Baja California. Calif. Coop. Ocean Fish. Invest. Report 13:32-38.

Meyers, N.L., et al. 1970. Adsorption of insecticides on pond sediments and watershed soils. Proc. Indiana Acad. Sci. 79(432).

Mitchell, F.K. 1974. Evaluating the impact of sludge discharge to Santa Monica Bay, California. In Rutgers/EPA symposium on the pretreatment and ultimate disposal of wastewater solids, May, 1974. SCCWRP Contribution 21.

Mitchell, F.K. 1975. Sediment trap applications in the near-shore region. SCCWRP Contribution 34.

Moen, A.N. 1968. The critical thermal environment: A new look at an old concept. Bioscience 18(11):1041-1043.

Moffatt and Nichol, Engineers. 1973. Final environmental impact report. Wilmington Liquid Bulk Terminals, Inc. Facility. Berth 187. Prepared for the Los Angeles Harbor Department Environmental Staff. 90 pp.

Mohr, J.L. 1953. The relationship of the areas of marine borer attack to pollution patterns in Los Angeles-Long Beach Harbors. Marine Borer Conf., 3rd, Marine Laboratory, Univ. of Florida, Coral Gables, Fla. 1952. Rpt. I1-I5.

Monais, A. 1970. Ion-exchange phenomena in clay suspensions in sea water. C.R.Acad. Sci. Ser. D 270(1743).

Montgomery, J.M. 1962. Report on water assimilation study of Dominguez Channel. December. Consulting Engineers, Inc.

Morgan, R.P. and R.G.Stross. 1969. Destruction of phytoplankton in the cooling water supply of a steam electric station. Chesapeake Science 10(3-4):165-171.

Morrison, R.L. 1957. Molluscan life and collecting in Mission Bay before and after dredging. Amer. Malac. Union, Annual Report. 28 pp.

Muga, B.J. and J.F.Wilson. 1970. Dynamic analysis of ocean structures. Plenum Press.

Murphy, W.L. 1974. Practices and problems in the confinement of dredged material in Corps of Engineers Projects. Army Engineers Waterways Experiment Station, Vicksburg, Miss. Rpt. No. AEWES-TR-D-74-2. 196 pp.

Napoli, J. 1972. Harbor sloshing. Sea Grant 70's 3(3):1.

National Research Council. 1976. Disposal in the marine environment: An oceanographic assessment. 76 p.

Nauman, J.W. and R.L.Cory. 1969. Thermal additions and epifaunal organisms at Chalk Point, Maryland. Chesapeake Science 10(3-4):218-226.

Nawrocki, M.A. 1974. Demonstration of the separation of disposal in concentrated sediments. Hittman Assoc., Columbus, Maryland. EPA/660/2-74-072. 86 pp.

Naylor, E. 1965. Effects of heated effluents upon marine and estuarine organisms. In Advances in Marine Biology. F.S. Russel, ed. Academic Press. 402 p.

Nelson, T.C. 1928. On the distribution of critical temperatures for spawning and for ciliary activity in bivalve molluscs. Science 67:220-221.

Newell. R. 1965. The role of detritus in the nutrition of two marine deposit feeders. Proc. Zool. Soc. London 144:25-45.

Nichols, D.R., et al. 1974. Seismic hazards and landuse planning. Geol. Survey Circular 690. U.S.Dept. of Interior, Washington, D.C.

Nimmo, D.R., et al. 1972. Toxicity and physiological activity of Arochlor 1254 to several estuarine organisms. Preprints, Water, Air and Waste Chem. Div., Amer. Chem. Soc., 164th Nat. Meeting, New York. p. 155.

Norse, E.A. 1974. Effects of subnormal temperatures on some common Los Angeles Harbor animals. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 3. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 44-62.

North, W. 1964. An investigation of the effects of discharged wastes on kelp. Calif. State Water Qual. Contr. Bd. Publ. No. 26.

North, W.J. 1971. Heated effluents and marine biota. Mimeo Rpt.

North, W.J. and J.R.Adams. 1969. The status of thermal discharges on the Pacific Coast. Chesapeake Sci.10(3-4):139-144.

Oertel, G.F. 1974. Report on the hydrologic and sedimentologic study of the offshore and spoil disposal area, Savannah, Georgia. Skidaway Inst. of Oceanography, Savannah, Ga. Rpt. No. Skidaway-2(1):1-111.

Office of Archaeology and Historic Preservation. 1971. The national register of historic places. Washington, D.C. GSPO

Oguri, M. 1974. Primary productivity in the outer Los Angeles Harbor. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 4. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 79-88.

Oguri, M., D.Soule, D.M.Juge, and B.C.Abbott. 1975. Red tides in the Los Angeles-Long Beach Harbor. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 8. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 109-119.

Okamoto, S. 1973. Introduction to Earthquake Engineering. John Wiley and Sons, New York.

O'Neal, G. 1971. The effects of dredging on water quality. World Dredging and Marine Construction 7(14):24-28.

Oppenheimer, C.H., and L.S.Kornicker. 1958. Effect of microbial production of hydrogen sulfide and carbon dioxide on the pH of recent sediments. Inst. of Marine Sci., Univ. Texas 5:5-15.

Ordal, E., Jr. and R.E.Pacha. 1963. The effects of temperature on disease in fish. In Proceedings of the Twelfth Pacific Northwest Symposium on Water Pollution. p. 39-55.

Ortolano, L. 1973. Analyzing the environmental impacts of water projects. Stanford Univ., Dept. of Civil Engineering. 433 pp.

Osburn, R.C. 1950-53. Bryozoa of the Pacific Coast of America. Parts 1-3, Univ. So. Calif. Press, Los Angeles.

Oshida, P. and D.J.Reish. 1974. The effect of various water temperatures on the survival and reproduction in polychaetous annelids: Preliminary report. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 3. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 63-77.

Parker, F.L. and P.A.Krenkel. 1969. Engineering aspects of thermal pollution. Vanderbilt Univ. Press. 351 pp.

Patel, B. and D.J.Crisp. 1960. The influence of temperature on the breeding and the moulting activities of some warm water species of operculate barnacles. J.Mar. Biol. Assoc., U.K. 39(3):667-679.

Pearce, J.B. 1969. Thermal addition and the benthos Cape Cod Canal. Chesapeake Science 10(3-4):227-233.

Pearson, E.A., P.M.Storrs and R.E.Selleck. 1967. Parameters of marine pollution. In Pollution and Marine Ecology. T.A. Olson and F.J.Burgess, eds. Interscience. pp. 297-315.

Pearson, J.G. 1975. Effects of discharge from a dredge spoils site on Carroll Island, Maryland. Edgewood Arsenal, Aberdeen Proving Ground, Maryland. Report No. EB-TR-75030. 19 p.

Pearson, J.R. 1969. Ships as sources of emissions. Pacific Northwest International Section of the Air Pollution Control Association. 69-AP-18.

Peter, W.G. 1970. New York Bight: A case study. Part II. Bioscience 29(11):669-671.

Pfitzenmeyer, H.T. 1970. Gross physical and biological effects of overboard spoil disposal in upper Chesapeake Bay. Project C: Benthos. Nat. Res. Inst., Spec. Rpt. 3.

Phelps, D.K., R.J.Santiago, D.Luciano, and M.Irizarry. 1969. Trace element composition of inshore and offshore benthic populations. Proc. 2nd Natl. Symp. Radioecol., Ann Arbor, Mich. D.J.Nelson and E.C.Evans, eds. p. 509.

Pickett, E.B., D.L.Durham, and W.H.McAnally. 1975. Los Angeles and Long Beach Harbors Model Study: Prototype data acquisition and observations. U.S.Army Engineers Waterways Experiment Station Hydraulics Laboratory. TR-H-75-4.

Pinter, P.A. 1973. Annotated bibliography on cannery effluents. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part II, Biological Investigations. Allan Hancock Foundation and Sea Grant Program. Univ. So. Calif., Los Angeles. 237 p.

Poland, J.F., et al. 1956. Ground-water geology of the coastal zone, Long Beach-Santa Ana, California. Geological Survey Water Supply Paper 1109.

Poland, J.F. 1956. Hydrology of the Long Beach-Santa Ana area, California. Geol. Survey Water Supply Paper 1471.

Presley, B.J., et al. 1967. Manganese and related elements in the interstitial water of marine sediments. Science 158 (906).

Proctor, R.J., R.Crook, Jr., M.H.McKeown, and R.L.Moresco. 1972. Relation of known faults to surface ruptures, 1971 San Fernando Earthquake, Southern California. Geol. Soc. Amer. Bull. 83:1601-1618.

Prosser, C.L. 1967. Molecular mechanisms of temperature adaption. Publ. No. 94, Amer. Assoc. Adv. Sci., Washington, D.C. 390 p.

Public Law 91-190. 1973. Title 40. Protection of the environment, Part 1500. Preparation of environmental impact statements: Guidelines. Federal Register 38:147.

Rashid, A.N. 1969. Contribution of humic substances to the cation exchange capacity of different marine sediments. Mar. Sediments 5(44).

Rauln, A.M. Narrative - C.S.D. Prepared for the County Sanitation Districts of Los Angeles.

Reish, D.J. 1952. Discussion of the colonial tube-building polychaetous annelid *Dodecaceria fistulicola*. Bull. So. Calif. Acad. Sci. 51:103-107.

Reish, D.J. 1954. The life history and ecology of the polychaetous annelid *Nereis grubei*. Allan Hancock Foundation Pub. Occas. Paper 14:1-74.

Reish, D.J. 1954. Polychaetous annelids as associates and predators of the crustacean wood-borer, *Limnoria*. Wasmann J. Biol. 12(2):223-226.

Reish, D.J. 1954. Nomenclatural changes and redescription of two Nereids (Annelida, Polychaeta) from the eastern Pacific. Bull. So. Calif. Acad. Sci. 53:99-106.

Reish, D.J. 1955. The relation of polychaetous annelids to harbor pollution. U.S.Publ. Health Serv., Publ. Health Rpt. 70(12):1168-1174.

Reish, D.J. 1957. Effect of pollution on marine life. Indust. Wastes 2:114-118.

Reish, D.J. 1957. The life history of the polychaetous annelid *Neanthes caudata* (delle Chiaje), including a summary of development in the family Nereidae. Pac. Sci. 11:216-228.

Reish, D.J. 1957. The relationship of the polychaetous annelid *Capitella capitata* (Fabricus) to waste discharges of biological origin. In Biological Problems in Water Pollution. C.M.Tarzwell, ed. p. 195-200. (Contrib. 208).

Reish, D.J. 1959. An ecological study of pollution in Los Angeles-Long Beach Harbors, California. Allan Hancock Found. Occas. Paper 22:1-119.

Reish, D.J. 1960. The use of marine invertebrates as indicators of water quality. Proc. of the 1st Intl. Conf. on Waste Disposal in the Mar. Environ. Pergammon Press, N.Y.:92-103.

Reish, D.J. 1960. A new species of Sabellidae (Annelida, Polychaeta) from southern California. Annals and Mag. Nat. Hist. London 13(2):717-719.

Reish, D.J. 1961. The use of the sediment bottle collector for monitoring polluted marine waters. Calif. Fish and Game 47:262-272.

Reish, D.J. 1961. The relationship of temperature and dissolved oxygen to the seasonal settlement of the polychaetous annelid *Hydroides norvegica* (Gunnerus). Bull. So. Calif. Acad. Sci. 60(1):1-11.

Reish, D.J. 1963. The effects of ocean water quality on bottom dwelling animals. ACS, Div. of Water and Waste Chemistry, New York, Sept. 8-13. p. 74-81.

Reish, D.J. 1964. Studies on the *Mytilus edulis* community in Alamitos Bay, California. II. Population variations and discussion of the associated species. Veliger:202-207.

Reish, D.J. 1964. The effect of oil refinery wastes on benthic marine animals in Los Angeles Harbor, California. In Pollutions Marines par les Microorganismes et les produits petroliers. Comm. Intl. pour l'exploration scientifique de le mer Mediterranee Monaco. 355-362.

Reish, D.J. 1967. Relationship of polychaetes to varying dissolved oxygen concentrations. Adv. in Water Poll. Res., Proc. 3rd Intl. Conf. Water Poll. Res. 3:199-216.

Reish, D.J. 1970. The effects of varying concentrations of nutrients, chlorinity, and dissolved oxygen on polychaetous annelids. Water Res. 4:721-735.

Reish, D.J. 1970. A critical review of the use of marine invertebrates as indicators of varying degrees of marine pollution. FAO Tech. Conf. on Mar. Poll. and its effects on living resources and fishing. Review Paper 9:1-13.

Reish, D.J. 1971. The effect of pollution abatement in Los Angeles Harbor, California. Mar. Poll. Bull 2:71-74.

Reish, D.J. 1971. Seasonal settlement of polychaetous annelids on test panels in Los Angeles-Long Beach Harbors, 1950-1951. J.Fish Res. Bd. Canada 28:1459-1467.

Reish, D.J. 1972. Biological changes in Los Angeles Harbor following pollution abatement. Calif. Mar. Res. Comm., CalCOFI Rpt. 16:118-121.

Reish, D.J. 1972. Marine estuarine pollution. Water Poll. Control Fed. J. 44(6):1218-1226.

Reish, D.J. 1972. Marine life of southern California. Donald J. Reish, Publ., Long Beach, California. 164 p.

Reish, D.J. 1973. The use of benthic animals in monitoring the marine environment. J. Env. Plan. and Poll. Control 1(3): 32-38.

Reish, D.J. and J.L.Barnard. 1959. Marine pollution. Water and Sewage Works. June.

Reish, D.J. and J.L.Barnard. 1960. Field toxicity tests in marine waters utilizing the polychaetous annelid *Capitella capitata* (Fabricus). Pac. Natur. 1:1-8.

Reish, D.J. and W.H.Hetherington, III. 1969. The effects of hyper- and hypo- chlorinities on members of the wood-boring genus *Limnoria*. Mar. Biol. 2:137-139.

Reish, D.J., A.J.Mearns, and T.W.Kauwling. 1975. Marine and estuarine pollution. J.Water Poll. Control. Fed. (June). SCCWRP Contribution 32.

Reish, D.J. and H.A.Winter. 1954. The ecology of Alamitos Bay, California, with special refeιence to pollution. Calif. Fish and Game 40:105-121.

Reisman, A. 1971. Managerial and engineering economics - a general decision and utility model and its applications. Allyn and Bacon, Inc. Boston. Mass.

Richards, A.P. 1953. The use of chlorination and heat in the control of marine borers. Rpt. Mar. Borer Conf., Univ. Miami, Coral Gables, Fla. Rpt. ML4719.

Richards, T.L. 1970. The influence of petroleum fractions in the polychaetous annelid *Nereis vexillosa*. West. Soc. Nat. Annual Meeting, 51st Abstract. p. 14-15.

Richardson, H.W. 1975. Economic aspects of the energy crisis. S.C.Heater and Co., Lexington, Mass.

Richie, D.E. 1970. Gross physical and biological effects of overboard spoil disposal in upper Chesapeake Bay, Project F. Fish. Nat. Res. Inst., Spec. Rpt. 3, Chesapeake Biol. Lab., Solomons, Md.

Richter, C.F. 1935. An instrumental earthquake magnitude scale. Seis. Soc. Amer. Bull. 25(1).

Richter, C.F. 1970. Seismicity of the Inglewood Fault and adjacent areas. Annual Meeting of the Seis. Soc. Amer.

Ricketts, E.F. and J.Calvin. 1962. Between Pacific Tides. Stanford Univ. Press, Stanford. 516 p.

Risebrough, R., D.R.Young, T.Munson, M.Goodwin, and R.Parrish. 1975. Contamination of marine resources for human consumption. In Proc. of the Marine Bioassay Workshop. SCCWRP Contribution 22.

Ritchie, J.C. 1972. Sediment, fish, and fish habitat. J. Soil Water Conserv. 27(3):124-125.

Robertson, A.R. 1905. Non-incrusting cheilostomatous Bryozoa of the west coast of North America. Univ. Calif. Publ. Zool. 2(5):235-322.

Robertson, A.R. 1908. The incrusting cheilostomatous Bryozoa of the west coast of North America. Univ. Calif. Publ. Zool. 4(5):253-344.

Robertson, A.R. 1910. The cyclostomatous Bryozoa of the west coast of North America. Univ. Calif. Publ. Zool. 6(12): 225-284.

Robinson, K. and H.Porath. 1974. Current measurements in the outer Los Angeles Harbor. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 6. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 1-91.

Rogers, B.A. 1969. The tolerance of fishes to suspended solids. MS Thesis, Univ. of Rhode Island.

Rubey, W.W. 1933. Settling velocities of gravel, sand, and silt particles. Amer. J. Science 23:325-338.

Ryther, J.H. and W.M.Dunstan. 1971. Nitrogen, phosphorus and eutrophication in the coastal marine environment. Science 171(3975).

Saila, S.B., S.D.Pratt, and T.T.Polgar. 1971. Providence Harbor improvement spoil disposal site evaluation study, Phase II. University of Rhode Island, Kingston, R.I.

Saila, S.B., T.T.Polgar, and B.A.Rogers. 1968. Results of studies related to dredged sediment dumping on Rhode Island Sound. Proc. Ann. Northeastern Reg. Antipoll. Conf.:71-80.

Saila, S.B., et al. 1972. Dredge spoil disposal in Rhode Island Sound. Rhode Island Univ., Kingston, Marine Experiment Station, Marine-TR-2, 54 p.

Salem, A.M. 1973. Consolidation characteristics of dredging slurries, ASCE Waterways, Harbors, and Coastal Engineering Division Journal 99:439-457.

Sanders, H.L. 1958. Benthic studies in Buzzards Bay. I. Animal-sediment relationships. Limnol. and Oceanogr. 3:245-358.

Sanger, J.E. and E.Gorham. 1971. The diversity of pigments in lake sediments and its ecological significance. Limnol. & Oceanogr. 15(59).

Schafer, R.D. and E.Swann. 1973. Free amino acid variation in the anchovy, *Engraulis mordax*, from the Los Angeles Harbor. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part II, Biological Investigations. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 21-28.

Schnabel, P.B. and H.B.Seed. 1973. Accelerations in rock for earthquakes in the western United States. Seis. Soc. Amer. Bull. 53(2).

Schwimmer, M. and P.Ammonson. 1973. Management of a seaport. U.S.Dept. of Commerce - Maritime Commission.

Science Applications, Inc. 1975. LNG Terminal risk assessment study for Los Angeles, California.

Science Engineering Associates. 1968. Wave and surge action study for Los Angeles-Long Beach Harbors. Final report prepared for the U.S.Army Corps of Engineers.

Scripps Institute of Oceanography. 1962. Results of current measurements with drogues, 1958-1961. Sponsored by the Mar. Res. Comm., State of California and Office of Naval Res. S10 Reference #62-27, December.

Sears, C.B. 1876. Principles of tidal harbor improvement as applied at Wilmington, California. Calif. Am. Soc. Civ. Engin. Trans. 5:388-426.

Security Pacific National Bank, Research Dept. 1975. Coastal zone economic study and statistical appendix.

Seed, H.B. 1975. Design provisions for assessing the effect of local geology and soil conditions on ground and building response during earthquake. Paper presented at earthquake symposium sponsored by SEAOC.

Seliger, H.E. 1970. On preparing for the advent of nuclear power. Bioscience 20(15):847.

Setzer, R. 1974. Preliminary investigations of benthic marine algae from the breakwaters protecting Los Angeles and Long Beach Harbors. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 4. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 89-101.

Sewage Industrial Wastes. 1956. Heat - a new pollutant. 28:705.

Shaheen, E.L. and W.Chantarasorn. 1971. Transport of shoal deposits. J. Water Poll. Control Fed. 43(872).

Shapiro, J. 1970. A statement of phosphorus. J. Water Poll. Control Fed. 42(772).

Sharma, G.D. 1970. Sediment-seawater interaction in glaciomarine sediments of southeast Alaska. Geol. Soc. Amer. Bull. 81(1097).

Sherk, J.A., et al. 1974. Effects of suspended and deposited sediments on estuarine organisms. Univ. Maryland, Solomon Natural Res. Inst., Rpt. No. 74-20, 229 p.

Sherk, J.S., Jr. 1971. The effect of suspended and deposited sediments on estuarine organisms. Univ. Maryland, Natl. Res. Inst., Chesapeake Biol. Lab., Contrib. 443. 73 p.

Sherwood, M.J, and A.J.Mearns. 1974. Disease responses in southern California coastal fishes. In Proceedings of the Conference on Marine Biology in Environmental Protection. T.A.Brody, ed. Rept. NUCTP 443, Naval Undersea Center, San Diego, California. p. 147-162. (SCCWRP Contrib. 17).

Sieburth, J.M. 1971. Binding and precipitation of trace elements by humic substances in natural waters. Graduate School of Oceanography, Rhode Island Univ.

Slack, K.V. 1971. August dissovled oxygen measurement and water quality significance. J. Water Poll. Contr. Fed. 43(3).

Slotta, L.S. 1973. Effects of hopper dredging and in-channel spoiling. Oregon State Univ., Interdisciplinary Studies of the School of Engineering. NSF GI-34346. 141 p.

Slotta, L.S., et al. 1974. An examination of some physical and biological impacts of dredging in estuaries. Oregon State Univ., NSF/RA/E-74-045. 264 p.

Smith, David D. and Associates, Environmental Quality Analysts and Marine Biological Consultants. 1974. Final environmental impact report, Chevron Chemical Co., Edgington Oil Co., Golden Eagle Refining Co. Prepared for the Los Angeles Harbor Department Environmental Staff.

Smith, E.T. and A.R.Morris. 1969. Systems analysis for optimal water quality management. J. Water Poll. Contr. Fed. 41(9): 1635-1646.

Smith, P.F. 1970. Modern instruments can help solve pollution problems. Ocean Industry 5(10):52-53.

Smith, R.G. and H.L.Windom. Analytical handbook for the determination of arsenic, cadmium, colbalt, copper, iron, lead, manganese, mercury, nickel, silver and zinc in the marine and estuarine environments. Georgia Mar. Sci. Center Tech. Rpt. Series #72-76.

Smith, R.W. 1973. Numerical analysis of a benthic transect in the vicinity of waste discharges in outer Los Angeles Harbor. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part II, Biological Investigations. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 193-237.

Snyder, D.R. 1968. Thermal plants, thermal pollution, and fish - the problems in the Columbia river and the Pacific northwest. Proc. Manuscript, U.S. Fish Wildlife Service Bur. Com. Fish., Biol. Lab., Seattle, Washington.

Socio-Economic Systems. 1973. Evaluation methodologies. S.E.S. -142.

Sorenson, A.H. 1971. Dredging benefits ecology. World Dredging and Marine Construction 7(11):55-56.

Sorenson, A.H. 1972. Clean water through dredging. Water and Sewage Works. R149-R150.

Soule, D.F. 1974. Thermal effects and San Pedro Bay. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 3. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 1-20.

Soule, D.F. and M.Oguri. 1972. Circulation patterns in Los Angeles-Long Beach Harbor. Drogue study: Atlas and Data Report. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part I. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles.

Soule, D.F. and M.Oguri. 1973. Preliminary investigations of the role of cannery wastes in the Los Angeles Harbor. An introduction. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part II, Biological Investigations. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. 237 p.

Soule, D.F. and M.Oguri. 1974. Data Report. Temperature, salinity, oxygen, and pH in outer Los Angeles Harbor. June 1971 to November, 1973. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 5. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles.

Soule, D.F. and M.Oguri. 1976. Physical water quality in the Long Beach area. Data report on temperature, salinity, oxygen, and pH and turbidity for the Port of Long Beach in 1973 and 1974. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 10. Allan Hancock Foundation and Sea Grant Program, Univ. So.'Calif., Los Angeles.

Soule, D.F. and M.Oguri. 1976. Potential ecological effects of hydraulic dredging in Los Angeles Harbor: An overview. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 11. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 1-14.

Soule, D.F., M.Oguri, and J.D.Soule. 1971. Development of environmental maintenance systems in the Los Angeles-Long Beach Harbor area. (Abstr.) In Second Coastal and Shallow Water Research Conference. Office of Naval Res. 327 p.

Soule, D.F. and J.D.Soule. 1972. Preliminary report on techniques for marine monitoring systems. Sea Grant Technical Note. USC-SG-1I-71.

South Coast Region of the California Coastal Zone Conservation Commission. 1974. Geology element of the south coast region. San Francisco.

Southern California Air Pollution Control District, Los Angeles Zone. 1975. Air quality and meteorology.

Southern California Air Pollution Control District, Los Angeles Zone. 1975. Air pollution control district digest.

Southern California Coastal Water Research Project. 1972. The ecology of the southern California bight: Implications for water quality management. Three-year report of SCCWRP. Volumes I and II.

Southern California Coastal Water Research Project. 1973. Baited camera observations of demersal fish. SCCWRP TM 207.

Southern California Coastal Water Research Project. 1974. A comparative trawl survey of three areas of heavy waste discharge. A.J.Mearns and C.S.Greene, eds. SCCWRP. 76 p.

Southern California Ocean Studies Consortium. 1974. A summary of knowledge of the southern California coastal zone and offshore areas. Volume I, Physical; Volume II, Biological; Volume III, Socio-Economic.

Southward, A.J. 1958. Note on the temperature tolerances of some intertidal animals in relation to environmental temperature and geological distribution. J. Mar. Biol. Assoc. U.K. 37:49-66.

Spaeth, M.G. and S.C.Berkman. 1967. The tsunami of March 28, 1964, as recorded at tide stations. U.S.Dept. of Commerce, E.S.S.A. Technical Report C and GS 33.

Squires, J.L., Jr. 1967. Surface temperature gradients observed in marine areas receiving warm water discharges. Tech. Pap., Bur. Sport Fish and Wildlife 11:1-8.

Stephens, J.S.,Jr., C.Terry, S.Subber, and M.J.Allen. 1974. Abundance, distribution, seasonality, and productivity of the fish populations in Los Angeles Harbor, 1972-73. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 4. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 1-42.

Stephens, J.S.,Jr., D.Gardiner and C.Terry. 1973. The demersal fish populations of San Pedro Bay. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part II, Biological Investigations. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles.

Stephenson, T.A. 1953. The world between tidemarks. In Essays in Marine Biology. London. p. 73-100.

Stone, R.B. 1963. A quantitative study of benthic fauna in lower Chesapeake Bay with emphasis on animal-sediment relationships. M.S. Thesis, School of Marine Science, College of William and Mary.

Straughan, D. and M.M.Patterson. 1975. Intertidal sandy beach macrofauna at Los Angeles-Long Beach Harbor. In Marine Studies of San Pedro Bay, California. D.Soule and M.Oguri, eds. Part 8. Allan Hancock Foundation and Sea Grant Program, Univ. So. Calif., Los Angeles. p. 75-108.

Stroud, R.H. and P.A.Douglas. 1968. Thermal pollution of water. Bull. Sport Fish. Inst. (191):1-8.

Sutton, R.J. 1971. Noise assessment guidelines. B.B.N. No. 2176.

Svante, O. and B.Berggren. 1970. Chlorinated hydrocarbons in soils and sediments. Grund Forebattring 23(5):85.

Tarzwell, C.M. 1970. Thermal requirements to protect aquatic life. J. Water Poll. Contr. Fed. 42(5):824-828.

Tarzwell, C.M. 1972. An argument for the open ocean siting of coastal thermal electric plants. J. Envir. Qual. 1(1): 89-91.

Tasler, J.D. and T.O.Munson. 1972. Movement of PCB's through the Chester River estuary. Preprints, Water, Air, and Waste Chem. Div., Am. Chem. Soc. 164th Natl. Meeting, New York. p. 59.

Taylor, C.C. 1959. Temperature and growth - the Pacific razor clam. J. Conseil. Intl. pour l'explor. de la mer 25:93-101.

Technical Subcommittee on Harbor Pollution. 1948. Second interim report. August 18.

Teng, T.L., C.R.Real, and T.L.Henyey. 1973. Micro-earthquakes and water flooding in Los Angeees. Seis. Soc. Amer. Bull. 63(3):859-875.

Theede, H., A.Ponat, K.Hiroki and C.Schlieper. 1969. Studies on the resistance of marine bottom invertebrates to oxygen deficiency and hydrogen sulfide. Mar. Biol. 2(4):325-337.

Thompson, J.R. 1973. Ecological effects of offshore dredging and beach nourishment. Govt. Rpts. Announcemts.77(8):1-44.

Topp, E. 1929. Physico-chemical studies of the seawater in the San Pedro Bay region. Changes in salinity, specific gravity, oxygen consumption throughout seasonal and tidal cycles with biological interpretations. Thesis, Univ. So. Calif., Los Angeles. 90 p.

Toth, S.J. and B.Gold. 1970. Agricultural value of dredged sediment. Final Report, Rutgers Univ., New Brunswick, N.J.

Trembley, F.J. 1960. Research project on effects of condensed discharge water on aquatic life. Prog. Rpt., 1959-60. Bethelem, Pa. Lehigh Univ,, Inst. of Research.

Turner, F.M. 1971. Clean water through dredging. Offshore technology conference. 3rd Annual, Vol. 1, Houston, Texas.

U.S. Army, Corps of Engineers. 1970. Los Angeles-Long Beach Harbors. Phase I, Background Material. Informal unpublished report prepared by the Los Angeles District, Corps of Engineers.

U.S.Army, Corps of Engineers. 1971. Los Angeles-Long Beach Harbors, interim review report. Los Angeles District, Corps of Engineers. June.

U.S.Army, Corps of Engineers. 1971. Working papers for environmental statement on Los Angeles-Long Beach Harbors. Los Angeles District, Corps of Engineers.

U.S.Army, Corps of Engineers. 1972. Los Angeles-Long Beach Harbors. Los Angeles District, Corps of Engineers.

U.S.Army Engineer District. 1968. Surveillance program of sedimentation effects of hydraulic dredging, Gulf intracoastal waterway, Bon Secour Bay section, July-Dec.,1967. Mobile, Alabama.

U.S.Army Engineer District. 1969. Long range spoil disposal study: Part II, Substury 1. Short range solution. Philadelphia, Pa.

U.S.Army Engineer District. 1970. Interim report on long-range spoil disposal study. Charleston Harbor, So. Carolina.

U.S.Army Engineer District. 1971. Dredge disposal study for San Francisco Bay and estuary: A preliminary report on main ship channel. San Francisco, Calif.

U.S.Army, Office, Chief of Engineers. 1971. Disposal of dredged materials. Engin-ering Circular 1165-2-97. U.S.Government printing office, Washington, D.C.

U.S.Atomic Energy Commission. 1974. As assessment of accident risks in the U.S.commercial nuclear power plants. Wash-1400.

U.S.Coast Guard. 1975. Regulations for crude oil carriage.

U.S.Congress and Seante. 1970. The national estuarine study. Report of the Secretary of the Interior to the U.S.Congress pursuant to Public Law 89-753: The clean water.

U.S.Dept. of Agriculture. 1963. Proceddings of the federal interagency sedimentation conference. Jackson, Miss., Misc. Publ. 970, Govt. Printing Office, Washington, D.C.

U.S.Dept. of Commerce. 1928-1970. U.S.earthquakes. Yearly reports. Washington, D.C.

U.S.Department of Housing and Urban Development. 1971. Noise abatement and control: Department policy. Implementation responsibilities and standards. U.S.Circular 1390.2.

U.S.Environmental Protection Agency. 1973. Compilation of air pollutant emission factors. 2nd ed. AP-42.

U.S.Environmental Protection Agency. 1974. Proceedings of the solvent reactivity conference. EPA 650/3-74-100.

U.S.Fish and Wildlife Service. 1970. Effects on fish resources of dredging and spoil disposal in San Francisco and San Pablo Bays, California. Washington, D.C.

Ukeles, R. 1961. The effects of temperature on the growth and survival of several marine algal species. Biol. Bull. 120: 255-264.

Ulrey, A.B. and P.O.Greedey. 1928. A list of marine fishes (teleostei) of southern California and their distribution. Bull. So. Calif. Acad. Sci. 27(1):1-53.

United States Federal Water Pollution Control Administration. 1961-1966. Fish kills by pollution.

University of California, Scripps Inst. of Oceanography. 1970. Data report. Surface water temperature at shore stations. United States West Coast. 1969. S.I.D. Reference 70-26.

Vernberg, F.J. and W.B.Vernberg. 1969. Thermal influence on invertebrate respiration. Chesapeake Sci. 10(3):234-240.

Voglin, R.M 1975. An otter trawl survey off Point Loma, San Diego, California. SCCWRP TM 220.

Wagner, G. 1968. Relation between the density of tubificid colonies and the available nutrient in the sediment. Natl. Rev. Cesamten. Hydrobiol. 53(715).

Wakeman, C.M., et al. 1948. Second interim report of the Technical Subcommittee on Harbor Pollution. 36 p.

Walton, B.C. 1965. The genus *Pylopagurus* (Crustacea: Anomura) in the Pacific with descriptions of two new species. Allan Hancock Pacific Expeditions 18:139-172.

Wang, S. 1974. A numerical model for simulation of oil spreading and transport and its applications for predicting oil slick movements in bays. Tetra Tech, Inc. Final Report. TT-P-345-74-1, February. 115 p.

Warden, W.R. 1957. The history and development of the artificial harbor of Los Angeles. Thesis, Univ. So. Calif., L.A.

Warinner, J.E. and M.L.Brekmer. 1966. The effects of thermal effluents on marine and organisms. Air and Water Poll. 10(4):277-289.

Wasserman, L.P. 1970. Economic loss of our estuarine resources to pollution damage. MTS Trans. of the 6th Annual Conf., Washington, D.C.

Wastes Engineering. 1961. Is heat pollution a threat to fish life? 32(7):348.

Wastler, T.A. and H.Berkson. 1970. Water quality monitoring for pollution control on the continental shelf. Oceans II Conf. Proc., p. 221-227.

West, P.J. 1970. Production and regulation of thermal discharge. Interstate conference on water problems. Portland, Oregon.

Widdows, J. and B.L.Bayne. 1971. Temperature acclimation of *Mytilus edulis* with reference to its energy budget. J. Mar. Biol. A-soc. U.K. 51:827-843.

Wiggins, J.H. and D.F.Moran. 1971 Earthquake safety in the city of Long Beach based on the concept of balanced risk. J.H. Wiggins Company.

Williams Brothers Engineering Co. 1975. SOHIO - Los Angeles to Midland Pipeline System Conversion Feasibility Study.

Williams Brothers Engineering Co. 1975. Data package. Station and Terminal electric power requirements. Prelim. Draft.

Williams Brothers Engineering Co. 1975. SOHIO - West coast midwest pipeline project, California Terminal Offshore Unloading system.

Williams, Kueblebeck, and Assoc. 1975. Socio-economic impact of the ports of Los Angeles and Long Beach. Marina del Rey.

Williamson, R.S. 1869. In United States Engineering Department report to the Chief Engineer. p. 479-482. Appendix V-2.

Williamson, R.S. 1871. In United States Engineering Department report to the Chief Engineer. p. 682-684. Appendix X-1.

Wilson, B.W. 1969. Elastic characteristics of moorings. Topics in Ocean Engineering.

Wilson, C.B. 1935. Parasitic copepods from the Pacific Coast. Amer. Midl. Nat. 16:776-797.

Windom, H.L. 1972. Environmental aspects of dredging in estuaries. ASCE Waterways, Harbors, and Coastal Engineering Division Journal 98, WW4. pp. 475-487.

Windom, H.L. 1972. Environmental aspects of dredging and filling. Proc. of Seminar on Planning and Engineering in the Coastal Zone. Charleston, So. Carolina. Seminar Series 2, 139 p.

Wood, E.J.F. and J.C.Ziemann. 1969. The effects of temperature on estuarine plant communities. Chesapeake Sci. 10(3-4): 172-174.

Wood, H.O., et al. 1934. Destructive and near-destructive earthquakes in California and western Nevada, 1769-1933. U.S. Dept. Comm., Coast and Geodetic Survey, Washington, D.C. Special Publication No. 191.

Woodward-Envicon, Inc. 1973. Final environmental impact report. Pacific Molasses Co., Wilmington Terminal. Prepared for the Los Angeles Harbor Department Environmental Staff. 62 p.

Word, J. and D.Charwat. 1974. Key to shrimp common in southern California trawl catches. SCCWRP TM 211.

Yeats, R.S. 1973. Newport-Inglewood fault zone, Los Angeles Basin, California. Amer. Assoc. Petro. Geol. Bull. 57(1).

Yerkes, R.F., et al. 1965. Geology of the Los Angeles Basin, California. U.S.Geol. Survey Profess. Paper 420A.

Young, C.S. 1971. Thermal discharges into the coastal waters of southern California. SCCWRP TR 102.

Young, D.R. 1971. Mercury in the environment: A summary of information pertinent to the distribution of mercury in the southern California bight. SCCWRP. 31 p.

Young, D.R. 1973. Trace contaminants in the southern California bight. In Proceedings of the Conference of Government Representatives on Discharges to the Pacific Ocean from Municipal Wastewater Treatment Facilities. Assoc. of Metro. Sewerage Agencies, Seattle, Washington, SCCWRP Contr. 20.

Young, D.R. 1974. Cadmium and mercury in the southern California bight. SCCWRP TM 216.

Young, D.R. 1975. A review of the chemical oceanography of the southern California offshore region. In Recommendation for baseline research in southern California relative to offshore resources development. So. Calif. Acad. Sci. L.A. R.J.Lavenberg and S.A.Earle, eds. p. 83-90. SCCWRP Contr. 40.

Young, D.R. and T.R.Folsom. 1972. Mussels and barnacles as indicators of the variation of ^{54}Mn, ^{60}Co, and ^{65}Zn in the marine environment. In Proceedings of the IAEA Symposium on Radioactive Contaminants in the Marine Environment. SCCWRP Contribution 5.

Young, D.R., T.R.Folsom, and Y.F.Hodge. 1975. ^{137}Cs and ^{40}K in the flesh of the Pacific albacore, 1964 to 1974. SCCWRP Contribution 28.

Young, D.R. and T.C.Heesen. 1974. Inputs and distributions of chlorinated hydrocarbons in three southern California harbors. SCCWRP TM 214.

Young, D.R., T.C.Heesen, D.J.McDermott, and P.E.Smokler. 1974. Marine inputs of polychlorinated biphenyls and copper from vessel antifouling paints. SCCWRP. 20 p.

Young, D.R., J.N.Johnson, A.Soutar, and J.D.Isaacs. 1973. Mercury concentrations in dated varved marine sediments collected off southern California. Nature 224:273-275.

Young, D.R. and D.J.McDermott. 1974. Trace metal anomalies in marine organisms off southern California. SCCWRP Contr. 39.

Young, D.R., C.S.Young, and G.E.Hlavka. 1973. Sources of trace metals from highly urbanized southern California to the adjacent marine ecosystems. In Cycling and Control of Metals. M.G.Curry and G.M.Gigliotti, eds. Natl. Environ. Res. Center, Cincinnati, Ohio. SCCWRP Contribution 6.

Young, P.H. 1964. Some effects of sewer effluent on marine life. Calif. Fish and Game Bull. 50(1):33-41.

Zeilbauer, E.J., H.A.Kues, W.L.Burnham, and A.G.Keene. 1962. Dominguez gap barrier project geologic investigation. Los Angeles Flood Control District.

Zobell, C.E. 1939. Occurrence and activity of bacteria in marine sediments. In Recent Marine Sediments: A Symposium. P.D.Trask, ed. American Assoc. Petrol. Geol.:416-427.

MARINE STUDIES OF SAN PEDRO BAY, CALIFORNIA

D. Soule and M. Oguri, editors

Published by Allan Hancock Foundation
and USC Sea Grant Program
University of Southern California

1972. Circulation patterns in Los Angeles-Long Beach Harbors. Drogue study atlas and data report. Part 1.

1973. Biological investigations: Preliminary investigations of the role of cannery wastes in the Los Angeles Harbor. Part 2.

An introduction. D.F.Soule and M.Oguri. p. 1-19.

Free amino acid variations in the anchovy, *Engraulis mordax*, from the Los Angeles Harbor. R.D.Schafer. p. 21-27.

The roles of microbial activity in the harbor ecosystem. D.M.Juge. p. 29-63

Working report on the dilution of cannery wastes discharges into the Los Angeles Harbor. J.E.Foxworthy. p. 65-77.

Annotated bibliography on cannery effluents. P.A. Pinter. p. 79-103.

Results of fourteen benthic trawls conducted in the outer Los Angeles-Long Beach Harbor, California. May 24, 1972. D.W. Chamberlain. p. 107-145.

The demersal fish populations of San Pedro Bay. J.S. Stephens, Jr. and D. Gardiner and C. Terry. p. 147-166.

Annotated bibliography on the northern anchovy, *Engraulis mordax* Girard. G.D. Brewer. p. 167-191.

Numerical analysis of a benthic transect in the vicinity of waste discharges in outer Los Angeles Harbor. R.W. Smith. p. 193-237.

a1974 Thermal tolerance and sediment toxicity studies. Marine Studies of San Pedro Bay, California, Part 3.

Thermal effects and San Pedro Bay. D.F. Soule. p. 1-20.

Preliminary observations on the lower minimum temperature requirements of the Northern Anchovy. G.D. Brewer. p. 21-43.

Effects of subnormal temperatures on some common Los Angeles Harbor animals. E.A. Norse. p. 44-62.

The effect of various water temperatures on the survival and reproduction in polychaetous annelids: Preliminary report. P. Oshida and D.J. Reish. p. 63-77.

Tolerance of *Littorina planaxis* and *L. Scutulata* to temperature changes (Mollusca, Gastropoda). D. Hadley and D. Straughan. p. 78-96.

Preliminary investigations of the effects of resuspended sediment on two species of benthic polychaetes from Los Angeles Harbor. R.R. Emerson. p. 97-110.

b1974 Environmental field investigations. Marine Studies of San Pedro Bay, California, Part 4.

Abundance, distribution, seasonality, and productivity of the fish populations in Los Angeles Harbor, 1972-73. J.S. Stephens, Jr., C. Terry, S. Subber, and M.J. Allen. p. 1-42.

A checklist of fishes from Los Angeles-Long Beach Harbors, D.W. Chamberlain. p. 43-78.

Primary productivity in the Outer Los Angeles Harbor. M. Oguri. p. 79-88.

Preliminary investigations of benthic marine algae from the breakwaters protecting Los Angeles and Long Beach Harbors. R. Setzer. p. 89-101.

c1974 Data report. Temperature, salinity, oxygen, and pH in Outer Los Angeles Harbor. June 1971 to November, 1973. Marine Studies of San Pedro Bay, California, Part 5. p. 1-76.

d1974 Circulation investigations: Current investigations in the Outer Los Angeles Harbor. K. Robinson and H. Porath. Marine Studies of San Pedro Bay, California, Part 6. p. 1-91.

e1974 Sediment investigations: Sediment compositions in Los Angeles-Long Beach Harbors and San Pedro Basin. K. Chen and J.C.S. Lu. Marine Studies of San Pedro Bay, California, Part 7. p. 1-177.

a1975 Environmental biology. Marine Studies of San Pedro Bay, California, Part 8.

The role of fish cannery waste in the ecosystem. D.W. Chamberlain. p. 1-22.

The biology and fishery of the northern anchovy in San Pedro Bay. Potential impact of proposed dredging and landfill. G.D. Brewer. p. 23-43.

A modification of B.O.D. method for use in the marine environment. D.M. Juge and G. Griest. p. 45-55.

Seasonal occurrence and distribution of benthic and fouling species of polychaetes in Long Beach. L.R. Hill and D.J. Reish. p. 57-74.

Intertidal sandy beach macrofauna at Los Angeles-Long Beach Harbor. Part 1, D. Straughan and M.M. Patterson. Part 2, D. Straughan. p. 75-107.

Red tides in the Los Angeles-Long Beach Harbor. M. Oguri, D.F. Soule, D.M. Juge and B.C. Abbott. p. 109-119.

b1975 Paleontology. G.L. Kennedy. Marine Studies of San Pedro Bay, California, Part 9. p. 1-119.

a1976 Physical water quality in the Long Beach Harbor area. A data report on temperature, salinity, oxygen, pH and turbidity for the Port of Long Beach in 1973 and 1974. Marine Studies of San Pedro Bay, California, Part 10. D. F. Soule and M. Oguri. p. 1-173.

b1976 Potential effects of dredging on the biota of Outer Los Angeles Harbor: Toxicity, bioassay, and recolonization study. Marine Studies of San Pedro Bay, California, Part 11.

Potential ecological effects of hydraulic dredging in Los Angeles Harbor: An overview. D.F. Soule and M. Oguri. p. 1-13.

Resuspended sediment elutriate studies on the northern anchovy. G.D. Brewer. p. 15-32.

Effects of Los Angeles Harbor sediment elutriate on the California killifish, *Fundulus parvipinnis* and white croaker, *Genyonemus lineatus*. D.W. Chamberlain. p. 33-47.

Toxicity and heavy metals in three species of crustacea from Los Angeles Harbor sediments. J.R. McConaugha. p. 49-67.

Bioassay and heavy metal uptake investigations of resuspended sediment on two species of polychaetous annelids. R.R. Emerson. p. 69-90.

Bioassay and recolonization studies in the Outer Los Angeles Harbor. D.F. Soule. p. 91-153.

Water quality evaluation of dredged material disposal from Los Angeles Harbor. K.Y. Chen and C.-C. Wang. p. 155-236.

Appendix I. Computer mapping of pollutants in Los Angeles Harbor. J.W.McDonald. p. 237-282.

Appendix II. Concentrations of trace elements and chlorinated hydrocarbons in marine fish. K.Chen and B.Eichenberger. p. 283-298.

Appendix III. Concentrations of trace metals in marine organisms. D.J.Reish and K.King. p. 299-314.

Appendix IV. Primary productivity, chlorophyll *a*. and assimilation ratios in Los Angeles-Long Beach Harbor, 1973 and 1974. M.Oguri. p. 315-325.

A LIST OF SPECIES, AS RECORDED IN THE LITERATURE, FROM LOS ANGELES-LONG BEACH HARBORS AREA TO 1973.

PHYLUM PORIFERA

Cyamon neon. DeLaubenfels, 1932, south San Pedro, 36 m. September, 1924.

Haliclona permollis. Reish, 1972.

Haliclona ecbasis. DeLaubenfels, 1932, floating dock at Wilmington.

Iophon chelifer. DeLaubenfels, 1932, south of San Pedro 48 m. December, 1961.

Microciona parthena. DeLaubenfels, 1932, south of San Pedro, 45 m. November, 1924.

Prosuberites sisyrnus. DeLaubenfels, 1932, south of breakwater, 45 m. April, 1924.

Stellata estrella. DeLaubenfels, 1932, 41 m. October, 1925.

PHYLUM COELENTERATA

Anthopleura elegentissima. Reish, 1972.

Diaduma leucolena. Reish, 1959, 1972.

Obelia sp. Reish, 1972; Abbott, Soule, Oguri & Soule, 1973 (settling rack).

Plocamia karykina, Reish, 1972.

Stylatula elongata. Reish, 1959, 1972.

Tubularia crocea. Barnard, 1958; Abbott, Soule, Oguri & Soule, 1973 (settling rack).

PHYLUM PLATYHELMINTHES

CLASS POLYCLADIDA

Acerotisa californica. Hyman, 1953.

Notoplana inquieta. Hyman, 1953.

Stylochus franciscanus. Hyman, 1953.

Stylochus insolitus. Hyman, 1953, coarse sand and shell bottom, 18 fms.

Stylochoplana longipenis. Hyman, 1953.

PHYLUM ANNELIDA

CLASS POLYCHAETA

Amaeana occidentalis. Hartman, 1966; Reish, 1959.

Ampharete sp. Hartman, 1966.

Ampharete labrops. Hartman, 1966; Abbott, Soule, Oguri & Soule, 1973 (benthic); Smith, 1973.

Amphicteis scaphobranchiata. Reish, 1959; Abbott, Soule, Oguri & Soule, 1973; Smith, 1973.

Amphisamytha bioculata. Abbott, Soule, Oguri & Soule, 1973 (benthic).

Anaitides sp. Reish, 1971; Hartman, 1966; Abbott, Soule, Oguri & Soule, 1973 (settling rack).

Anatides williamsi. Reish, 1959; Abbott, Soule, Oguri & Soule, 1973 (benthic); Smith, 1973.

Ancistrosyllis sp. Hartman, 1966.

Ancistrosyllis bassi. Reish, 1959.

Ancistrosyllis hamata. Abbott, Soule, Oguri & Soule, 1973 (benthic).

Ancistrosyllis tentaculata. Hartman, 1955.

Anotomastus gordiodes. Hartman, 1966.

Arabella semimaculata. Hartman, 1966.

Aricidea sp. Hartman, 1966.

Aricidea lopezi. Hartman, 1966.

Aricidea neosuecica. Hartman, 1966.

Aricidea suecica. Smith, 1973.

Armandia bioculata. Crippen & Reish, 1969; Hartman, 1966; Reish, 1959, 1971; Abbott, Soule, Oguri & Soule, 1973 (settling rack and benthic); Smith, 1973.

Asychis sp. Hartman, 1966.

Asychis disparidentata. Reish, 1959.

Autolytus sp. Crippen & Reish, 1969; Reish, 1971; Abbott, Soule, Oguri & Soule, 1973 (settling rack)

Autolytus prismaticus. Reish, 1971

Ariothella rubrocincta. Reish, 1969; Smith, 1973.

Boccardia sp. Hartman, 1966.

Boccardia basilaria. Hartman, 1966.

Boccardia polybranchia. Reish, 1959; Abbott, Soule, Oguri and Soule, 1973 (benthic).

Boccardia proboscidea. Crippen & Reish, 1969; Reish, 1971.

Boccardia redeki. Hartman, 1966.

Brada pilosa. Hartman, 1966.

Brada villosa. Hartman, 1966.

Brania limbata. Reish, 1971.

Capitella capitata. Crippen & Reish, 1969; Reish, 1959, 1961; Abbott, Soule, Oguri & Soule, 1973(benthic).

Capitella capitata oculata. Smith, 1973.

Capitita ambiseta. Reish, 1959; Abbott, Soule, Oguri & Soule, 1973 (benthic); Smith, 1973.

Carazzia sp. Reish, 1959 (=*Polydora*)

Chaetopterus variopedatus. Allan Hancock FOund., 1965.

Chaetozone corona. Hartman, 1955, 1966; Reish, 1959; Abbott, Soule, Oguri & Soule, 1973 (benthic); Smith, 1973.

Chone gracilis. Hartman, 1966.

Chone minuta. Reish, 1959.

Chone mollis. Hartman, 1966; Reish, 1959; Abbott, Soule, Oguri & Soule, 1973 (benthic).

Cirratulus cirratus. Hartman, 1966; Reish, 1959.

Cirriformia luxuriosa. Hartman, 1966; Reish, 1959, 1972.

Cirriformia spirabrancha. Hartman, 1966; Reish, 1959; Abbott, Soule, Oguri & Soule, 1973 (benthic).

Cirrophorus furcatus. Hartman, 1966.

Cossura candida. Hartman, 1955, 1966; Reish, 1959; Abbott, Soule, Oguri & Soule, 1973 (benthic).

Ctenodrilus serratus. Crippen & Reish, 1969; Reish, 1971; Abbott, Soule, Oguri & Soule, 1973 (rack).

Diopatra ornata. Hartman, 1944, 1966; Reish, 1959.

Diopatra splendidissima. Reish, 1959.

Diopatra tridendata. Hartman, 1966; Reish, 1959.

Dorvillea articulata. Hartman, 1966; Reish, 1959; Abbott, Soule, Oguri & Soule, 1973 (benthic).

Drilonereis falcata. Abbott, Soule, Oguri & Soule, 1973 (benthic).

Drilonereis longa. Hartman, 1966.

Drilonereis nuda. Hartman, 1966; Reish, 1959.

Eunice antennata. Hartman, 1944, San Pedro breakwater.

Eteone sp. Hartman, 1966; Reish, 1971; Abbott, Soule, Oguri & Soule, 1973 (benthic).

Eteone californica. Hartman, 1966; Reish, 1959; Smith, 1973.

Eteone dilatae. Hartman, 1966; Abbott, Soule, Oguri & Soule, 1973 (benthic).

Euchone sp. Reish, 1959.

Euchone limnicola. Abbott, Soule, Oguri & Soule, 1973 (benthic); Smith, 1973.

Euchone incolor. Smith, 1973.

Eumida sp. Abbott, Soule, Oguri & Soule, 1973 (benthic).

Eumida bifoliata. Hartman, 1966.

Eumida sanguinea. Reish, 1971; Abbott, Soule, Oguri & Soule, 1973 (benthic and settling rack); Smith, 1973.

Eupomatus gracilis. Crippen & Reish, 1969.

Eusyllis transecta. Reish, 1971

Exogone sp. Abbott, Soule, Oguri & Soule, 1973 (settling rack).

Exogone lourei. Crippen & Reish, 1969; Reish, 1972.

Fabricia sp. Hartman, 1966.

Glycera americana. Hartmar, 1966; Reish, 1969, 1972; Abbott, Soule, Oguri & Soule, 1973 (benthic).

Glycera capitata. Hartman, 1966.

Glycinde armigera. Abbott, Soule, Oguri & Soule, 1973 (benthic).

Goniada brunnea. Hartman, 1966; Abbott, Soule, Oguri & Soule, 1973 (benthic).

Goniada littorea. Hartman, 1966; Reish, 1959.

Gyptis avenicola glabra. Hartman, 1966; Smith, 1973.

Halosydna brevisetosa. Crippen & Reish, 1959; Reish, 1971; Abbott, Soule, Oguri & Soule, 1973 (settling rack).

Halosydna johnsoni Crippen & Reish, 1959; Reish, 1961.

Haploscoloplos elongatus. Hartman, 1966; Reish, 1959, 1972; Abbott, Soule, Oguri & Soule, 1973 (benthic); Smith, 1973.

Harmothoe lunulata. Hartman, 1966.

Harmothoe priops. Hartman, 1966; Smith, 1973.

Hesperonoe complanata. Reish, 1959.

Hesperonoe laevis. Abbott, Soule, Oguri & Soule, 1973 (benthic sample).

Hydroides pacificus. Reish, 1971, 1972; Abbott, Soule, Oguri & Soule, 1973 (settling rack).

Hydroides norvegica. Crippen & Reish, 1969; Reish, 1961.

Hypoeulalia bilineata. Reish, 1959.

Langerhansia heterochaeta. Reish, 1971.

Laonice cirrata. Hartman, 1966; Reish, 1959; Abbott, Soule, Oguri & Soule, 1973 (benthic).

Laonice foliata. Abbott, Soule, Oguri & Soule, 1973 (benthic); Smith, 1973.

Loandalia fauveli. Hartman, 1966.

Lumbrinereis sp. Hartman, 1955, black mud, 6 fms; Abbott, Soule, Oguri & Soule, 1973 (benthic).

Lumbrineris californiensis. Hartman, 1966; Smith, 1973.

Lumbrineris cruzensis. Hartman, 1966.

Lumbrineris erecta. Hartman, 1944, San Pedro breakwater; Reish, 1959, 1972; Abbott, Soule, Oguri & Soule, 1973 (benthic).

Lumbrineris index. Hartman, 1944, San Pedro Channel, green sand; Smith, 1973.

Lumbrineris latreilli. Reish, 1959.

Lumbrineris latreilli japonica. Reish, 1959.

Lumbrineris limicola. Hartman, 1966; Smith, 1973.

Lumbrineris minima. Hartman, 1966; Reish, 1959, 1972; Abbott, Soule, Oguri & Soule, 1973 (benthic).

Lumbrineris pallida. Hartman, 1966.

Lumbrineris zonata. Hartman, 1966; Smith, 1973

Magelona sp. Hartman, 1966.

Magelona pacifica. Abbott, Soule, Oguri & Soule, 1973 (benthic).

Magelona pitelkai. Smith, 1973.

Magelona sacculata. Hartman, 1966.

Maldane sarsi. Hartman, 1966.

Marphysa disjuncta. Hartman, 1966; Abbott, Soule, Oguri & Soule, 1973 (benthic).

Mediomastus californiensis. Hartman, 1966.

Megalomma sp. Hartman, 1966.

Melinna sp. Hartman, 1966.

Melinna cristata. Hartman, 1966.

Melinna denticulata. Hartman, 1966.

Melinna heterodonta. Hartman, 1966.

Melinna oculata. Abbott, Soule, Oguri & Soule, 1973 (benthic); Smith, 1973.

Myxicola sp. Reish, 1959.

Naineris dendritica. Crippen & Reish, 1969.

Neanthes arenaceodentata. Reish, 1972.

Neanthes caudata. Reish, 1959.

Neanthes succinea. Crippen & Reish, 1969.

Nephtys sp. Hartman, 1966.

Nephtys caecoides. Reish, 1959; Abbott, Soule, Oguri & Soule, 1973 (benthic); Smith, 1973.

Nephtys californiensis. Abbott, Soule, Oguri & Soule, 1973 (benthic).

Nephtys cornuta. Hartman, 1966.

Nephtys cornuta franciscana. Abbott, Soule, Oguri & Soule, 1973 (benthic); Smith, 1973.

Nephtys ferruginea. Hartman, 1966; Reish, 1959; Abbott, Soule, Oguri & Soule, 1973 (benthic).

Nereis grubei. Crippen & Reish, 1969; Reish, 1972.

Nereis latescens. Reish, 1959, 1972.

Nereis procera. Hartman, 1966; Reish, 1969; Abbott, Soule, Oguri & Soule, 1973 (benthic); Smith, 1973.

Ninoe gemmea. Hartman, 1966.

Nothria elegans. Smith, 1973.

Nothria iridenscens. Hartman, 1966; Reish, 1959.

Nothria stigmatis. Jones, 1965, areas of course red sand in San Pedro Bay.

Notomastus tenuis. Hartman, 1966; Abbott, Soule, Oguri & Soule, 1973 (benthic); Smith, 1973.

Odontosyllis phosphurea. Reish, 1971.

Onuphis eremita. Hartman, 1944.

Ophiodromus pugettensis. Hartman, 1966; Reish, 1971; Abbott, Soule, Oguri & Soule, 1973 (benthic).

Owenia collaris. Hartman, 1966.

Owenia fusiformis collaris. Reish, 1959.

Paleanotus bellis. Reish, 1971; Abbott, Soule, Oguri & Soule, 1973 (rack).

Paraonis gracilis. Hartman, 1966.

Paraonis gracilis oculata. Reish, 1959; Abbott, Soule, Oguri & Soule, 1973 (benthic); Smith, 1973.

Pectinaria californiensis. Reish, 1959; Abbott, Soule, Oguri & Soule, 1973 (benthic).

Peisidice aspera. Hartman, 1966; Reish, 1959; Abbott, Soule, Oguri & Soule, 1973 (benthic).

Pherusa capulata. Reish, 1959.

Pherusa inflata. Reish, 1959.

Pherusa neopapillata. Reish, 1959; Abbott, Soule, Oguri & Soule, 1973 (benthic); Smith, 1973.

Pholoe glabra. Hartman, 1966; Abbott, Soule, Oguri & Soule, 1973 (benthic); Smith, 1973.

Phyllodocids, juvenile. Abbott, Soule, Oguri & Soule, 1973.

Pilargis berkeleyi. Hartman, 1966.

Pilargis maculata. Hartman, 1966.

Pista cristata. Hartman, 1966; Abbott, Soule, Oguri & Soule, 1973 (benthic).

Pista fasciata. Smith, 1973.

Pista disjuncta. Hartman, 1966.

Platynereis bicanaliculata. Crippen & Reish, 1969; Reish, 1959, 1961, 1971, 1972; Abbott, Soule, Oguri & Soule, 1973 (benthic and rack).

Podarke pugettensis. Reish, 1959, 1961.

Poecilochaetus johnsoni. Hartman, 1966.

Polycirrus sp. Hartman, 1966.

Polydora sp. Hartman, 1966; Smith, 1973.

Polydora armata. Hartman, 1966.

Polydora brachycephala. Reish, 1959; Abbott, Soule, Oguri & Soule, 1973 (benthic); Smith, 1973.

Polydora cirrosa. Reish, 1959.

Polydora citrona. Hartman, 1966.

Polydora limicola. Crippen & Reish, 1969; Reish, 1971; Abbott, Soule, Oguri & Soule, 1973 (benthic and settling rack).

Polydora pancil. Abbott, Soule, Oguri & Soule, 1973 (benthic).

Polydora paucibranchiata. Reish, 1959, 1961.

Polydora socialis. Abbott, Soule, Oguri & Soule, 1973 (benthic); Smith, 1973.

Polydora tricuspa. Crippen & Reish, 1969.

Polyopththalamus pictus. Abbott, Soule, Oguri & Soule, 1973 (settling rack).

Potamilla sp. Reish, 1959.

Praxillella affinis pacifica. Hartman, 1966.

Prionospio cirrifera. Hartman, 1966; Reish, 1959; Abbott, Soule, Oguri & Soule, 1973 (settling rack); Smith, 1973.

Prionospio heterobranchia newportensis. Reish, 1959; Smith, 1973.

Prionospio malmgreni. Hartman, 1966; Abbott, Soule, Oguri & Soule, 1973 (benthic); Smith, 1973.

Prionospio pinnata. Hartman, 1966; Reish, 1959; Abbott, Soule, Oguri & Soule, 1973 (benthic); Smith, 1973.

Prionospio pygmaeus. Reish, 1971; Abbott, Soule, Oguri & Soule, 1973 (benthic); Smith 1973.

Pseudopolydora paucibranchiata. Reish, 1968; Smith, 1973.

Scalibregma inflatum. Hartman, 1966; Reish, 1959.

Schistocomus hiltoni. Hartman, 1966.

Sigambra bassi. Abbott, Soule, Oguri & Soule, 1973 (benthic).

Sigambra tentaculata. Abbott, Soule, Oguri & Soule, 1973 (benthic); Smith, 1973.

Sphaerosyllis sp. Hartman, 1966.

Spiochaetopterus sp. Reish, 1959.

Spiophanes berkelyorum. Smith, 1973.

Spiophanes bombyx. Jones, 1965; coarse red sand; Smith, 1973.

Spiophanes fimbriata. Hartman, 1966.

Spiophanes missionensis. Hartman, 1966; Reish, 1959, 1972; Smith, 1973.

Spiophanes pigmentata. Reish, 1959.

Stauronereis rudulphi. Crippen & Reish, 1969; Reish, 1971, 1972; Smith, 1973.

Sternaspis fossor. Hartman, 1966.

Sthenelanella uniformis. Hartman, 1939, 1966.

Streblosoma crassibranchia. Hartman, 1966.

Streblospio crassibranchiata. Reish, 1959; Smith, 1973.

Syllidea sp. Crippen & Reish, 1969.

Syllis gracilis. Reish, 1971.

Telepsavus costarum. Hartman, 1966; Abbott, Soule, Oguri & Soule, 1973 (benthic); Smith, 1973.

Terebellides stroemii. Hartman, 1966; Reish, 1959.

Tharyx monilaris. Hartman, 1966.

Tharyx multifilis. Reish, 1959.

Tharyx parvus. Reish, 1959; Abbott, Soule, Oguri & Soule, 1973 (benthic).

Tharyx tesselata. Allan Hancock Found., 1965; Hartman, 1966.

Thelepus setosus. Abbott, Soule, Oguri & Soule, 1973 (benthic).

Travisia sp. Hartman, 1966.

Typosyllis fasciata. Reish, 1971.

PHYLUM ENTOPROCTA

Barentsia discreta. Osburn, 1953, off San Pedro breakwater, 17 fms.

Barentsia gracilis. Robertson, 1900; Osburn, 1953.

PHYLUM MOLLUSCA

CLASS GASTROPODA

Acanthina paucilirata. McLean, 1969, upper intertidal zone.

Acteocina magdalensis. Reish, 1959.

Acteon punctocoelata. Hartman, 1966; Reish, 1959.

Acteon ? traskii. Reish, 1959.

Aglaja sp. Hartman, 1966.

Alabina occidentalis. Reish, 1959.

Aplysia vaccaria. Lance, 1961, common intertidally.

Balcis rutila. Hartman, 1966.

Barleeia californica. McLean, 1969, low tide and sublittoral zones, under kelp.

Bittium quadrifilatum. McLean, 1969, shallow water.

Bulla gouldiana. Reish, 1972.

Cerithidea californica. Reish, 1972.

Chromodoris californiensis. McFarland, 1966, collected by Cockerell, Eliot & Guernsey in 1901, 1905, 1912.

Colus sp. Reish, 1959.

Crepidula sp. Hartman, 1966.

Crepidula aculeata. Hartman, 1966.

Crepidula onyx. Reish, 1959, 1972.

Crucibulum spinosum. McLean, 1969.

Cylichna attonsa. Hartman, 1966.

Cylichna diegensis. Hartman, 1966.

Dirona picta. McFarland, 1966, collected by Cockerell in 1900.

Fusinus kobetti. Reish, 1959.

Glossodoris macfarlandi. McFarland, 1966, San Pedro; Lance, 1961, uncommon, sublittoral to 30 feet.

Hermissenda crassicornis. McFarland, 1966, collected by Cockerell in 1900 at San Pedro.

Hopkinsia rosacea. McFarland, 1966, collected by Cockerell in 1900 and 1905 at San Pedro.

Mangelia sp. Hartman, 1966.

Mangelia barbarensis. Hartman, 1966.

Murex festivus. Chace & Chace, 1967, collected in 1926.

Nassarius cooperi. Hartman, 1966.

Nassarius fossatus. Reish, 1959.

Nassarius perpinguis. Hartman, 1966.

Notoacmea paleacea. McLean, 1969.

Odostomia sp. Hartman, 1966.

Olivella baetica. Hartman, 1966.

Ophiodermella incisa. Hartman, 1966.

Peristichia pedroana. McLean, 1969, low tide to sublittoral zones.

Pleurobranchus californicus. McFarland, 1966, San Pedro, 1900; Lance, 1961.

Pleurobranchus digueti. Lance, 1961.

Pleurobranchus strongi. McFarland, 1966, San Pedro in 1921.

Polycera atra. Reish, 1972.

Pterynotus trialatus. Fitch, 1963, found on live fish.

Pyramidella adamsi. McLean, 1969.

Rissoina dalli. McLean, 1969.

Pseudomelotoma grippi. McLean, 1969, rocky bottoms, under kelp.

Spurilla chromosoma. Lance, 1961, rare intertidally.

CLASS PELECYPODA

Adontorhina cyclia. Hartman, 1966.

Aloidis luteola. Reish, 1959.

Asthenothaerus villosior. Hartman, 1966.

Axinopsis sericatus. Reish, 1959.

Bankia setacea. Horvath, 1951; Menzies, 1964, colder stations near harbor entrance.

Chione sp. Abbott, Soule, Oguri & Soule, 1973 (settling rack).

Chione fluctifraga. Reish, 1959.

Chione undatella. Hartman, 1966; Reish, 1959.

Chlamys sp. Hartman, 1966.

Compsomyax subdiaphana. Hartman, 1966; Reish, 1959.

Cooperella subdiaphana. Reish, 1959.

Crenella decussata. Reish, 1959.

Cryptomya californica. Reish, 1959.

Hiatella arctica. Reish, 1959, 1972; Abbott, Soule, Oguri & Soule, 1973.

Kellia sp. Hartman, 1966.

Laevicardium substriatum. Reish, 1959.

Leptopecten latiauratus. Abbott, Soule, Oguri & Soule, 1973 (settling rack).

Lucinisca nuttalli. Hartman, 1966.

Lucinoma annulata. Hartman, 1966.

Lyonsia californica. Hartman, 1966.

Lyrodus pedicellatus (=Teredo diegensis). Reish, 1972.

Lysonia californica. Reish, 1959.

Macoma sp. Hartman, 1966.

Macoma indentata. Hartman, 1966.

Macoma nasuta. Hartman, 1966; Reish, 1959, 1972.

Macoma secta. Reish, 1959.

Macoma goldiformis. Hartman, 1966.

Mactra californica. Hartman, 1966.

Modiolus sp. Hartman, 1966.

Modiolus capax. Chace & Chace, 1967, found in 1926 on docks of yacht harbor; Reish, 1959.

Modiolus neglectus. Hartman, 1966.

Mya sp. Reish, 1959.

Mytilus sp. Menzies, 1964; Reish, 1959.

Mytilus edulis. Crippen & Reish, 1969; Abbott, Soule, Oguri & Soule, 1973 (settling rack).

Nuculana taphria. Hartman, 1966.

Parvilucina tenuisculpta. Hartman, 1966.

Periploma discus. Hartman, 1966.

Petricola sp. Abbott, Soule, Oguri & Soule, 1973 (settling rack).

Petricola (Rupellaria) californiensis. Reish, 1959.

Protothaca staminea. Reish, 1959.

Protothaca tenerrima. Hartman, 1966.

Psephidia ovalis. Reish, 1959.

Rochefortia sp. Hartman, 1966.

Saxidomus nuttalli. Reish, 1959.

Solamen columbianum. Hartman, 1966.

Solen rosaceus. Hartman, 1966; Reish, 1959.

Solen sicarius. Hartman, 1966.

Tagelus californianus. Hartman, 1966; Reish, 1959.

Tellina buttoni. Hartman, 1966.

Tellina carpenteri. Hartman, 1966.

Tellina idae. Hartman, 1966; Reish, 1959.

Teredo navalis. Horvath, 1951.

Teredo diegensis. Horvath, 1951; Menzies, 1964.

Thyasira sp. Hartman, 1966.

Thyasira barbarensis. Reish, 1959; Hartman, 1966.

Tentaturris janira. McLean, 1969, low tide, rocky areas.

Tephtys sp. Reish, 1959.

Terebra pedroana. McLean, 1969, offshore, sandy bottom.

Tritonalia poulsoni. Chace & Chace, 1967, found in 1926 around docks of boat harbor.

Tritonia palmeri. Lance, 1961

Turbonilla sp. Hartman, 1966.

Tylodina fungina. McFarland, 1966, collected by Dall in 1900's.

Volvulella tenuissima. Hartman, 1966.

Vitrinella sp. Hartman, 1966.

CLASS SCAPHOPODA

Cadulus sp. Hartman, 1966.

Cadulus fusiformis. Hartman, 1966.

Dentalium sp. Hartman, 1966; Reish, 1959.

PHYLUM ARTHROPODA

CLASS CRUSTACEA

Subclass Copepoda

Amphiancus sp. Barnard & Reish, 1957, found boring into wooden test panels.

Harpacticoid copepods. Abbott, Soule, Oguri & Soule, 1973 (settling rack).

Nemesis lamna. Wilson, 1935, from *Lamna cornibica* (shark).

Tisbe sp. Barnard & Reish, 1957, found boring into wooden test panels.

Tisbe gracilis. Barnard & Reish, 1960 on surfaces of wooden test panels.

Subclass Cirripedia

Balanus sp. Reish, 1961.

Balanus amphitrite. Reish, 1972; Abbott, Soule, Oguri & Soule, 1973 (settling rack).

Balanus crenatus. Reish, 1972.

Subclass Malacostraca

ORDER LEPTOSTRACA

Epinebalia sp. Reish, 1959, 1972.

ORDER MYSIDACEA

Boreomysis californica. Banner, 1954, San Pedro Channel.

Eucopia australis. Banner, 1954, San Pedro Channel.

ORDER CUMACEA

Diastylopsis tenuis. Barnard & Givens, 1961.

ORDER ISOPODA

Caecijaera horvathi. Menzies, 1951, southwest corner of Terminal Island from wood infested with *Limnoria*.

Limnoria quadripunctata. Barnard, 1950; Menzies, 1957, 1958, 1964, occupy areas of colder water.

Limnoria tripunctata. Menzies, 1952, 1964, 1958, occupy areas of warmer water; Reish, 1972.

ORDER AMPHIPODA

Amphipods, juvenile. Abbott, Soule, Oguri & Soule, 1973 (settling rack).

Ampelisca cirstata. Reish, 1959.

Caprella sp. Barnard, 1958; Abbott, Soule, Oguri & Soule, 1973 (settling rack).

Caprella californica. Keith, 1969, Long Beach Marina; Abbott, Soule, Oguri & Soule, 1973 (settling rack).

Caprella equilibra. Keith, 1969, Long Beach Marina; Abbott, Soule, Oguri & Soule, 1973 (settling rack).

Caprella verrucosa. Abbott, Soule, Oguri & Soule, 1973 (settling rack).

Chel⁻ra terebrans. Barnard, 1950, 1955; Reish, 1972.

Corophium sp. Menzies, 1964; Reish, 1959.

Corophium acherusicum. Reish, 1959, 1961, 1972; Abbott, Soule, Oguri & Soule, 1973 (settling rack).

Corophium insidiosium. Reish, 1959.

Cystisoma fabricii. Hurley, 1956.

Elasmopus rapax. Reish, 1959; abbott, Soule, Oguri & Soule, 1973 (settling rack).

Eupronoe minuta. Hurley, 1956.

Hyperia bengalensis. Hurley, 1956.

Jassa falcata. Reish, 1972; Abbott, Soule, Oguri & So8le, 1973 (settling rack).

Microjassa litotes. Barnard, 1954, on submerged wooden test blocks.

Paraphoxus sp. Reish, 1959.

Paraphronima crassipes. Hurley, 1956.

Paraphronima gracilis. Hurley, 1956.

Photis californica. Reish, 1959.

Phronima sedentaria. Hurley, 1956.

Podocerus brasiliensis. Barnard, 1953; Reish, 1959; Abbott, Soule, Oguri & Soule, 1973 (settling rack).

Primno macropa. Hurley, 1956.

Scina borealis. Hurley, 1956.

Scina tullbergi. Hurley, 1956.

Stenothoe valida. Barnard, 1958; Abbott, Soule, Oguri & Soule, 1973 (settling rack).

Streetsia pronoides. Hurley, 1956.

Vibilia armata. Hurley, 1956.

Vibilia viatrix. Hurley, 1956.

ORDER EUPHAUSIACEA

Euphausea gibboides. Banner, 1954.

Euphausia pacifica. Banner, 1954.

Nematoscelis difficilis. Banner, 1954.

Nyctiphanes simplex. Banner, 1954.

Stylocheiron maximum. Banner, 1954.

Thysanoessa spinifera. Banner, 1954.

ORDER DECAPODA

Callianassa californiensis. Reish, 1959, 1972.

Cancer productus. Reish. 1972.

Crangon californiensis. Reish, 1972.

Lepidopa myops. McGinitie & McGinitie, 1968, burrow in sand.

Pinnixa franciscana. Reish, 1959, 1972, burrows of *Callianassa californiensis*.

Pylopagurus holmesi. Waltan, 1965.

PHYLUM PHORONIDA

Phoronis architecta. Reish, 1959.

Phoronis pallida. Reish, 1969.

Phoronis psammophila. Reish, 1959.

Phoronis vancouverensis. Reish, 1972.

Phoronopsis harmeri. Reish, 1959.

PHYLUM BRYOZOA

CLASS GYMNOLAEMATA

Suborder Anasca

Aetea anguina. Robertson, 1905.

Bugula californica. Reish, 1972; Abbott, Soule, Oguri & Soule, 1973 (settling rack).

Bugula neritina. Reish, 1961; Abbott, Soule, Oguri & Soule, 1973 (settling rack).

Callopora horrida. Osburn, 1952, off breakwater of San Pedro.

Cellaria diffusa. Robertson, 1905.

Chapperia californica. Osburn, 1950.

Dendrobeania laxa. Osburn, 1950, off San Pedro breakwater, 17-19 fms.

Figularia hilli. Osburn, 1950, off San Pedro breakwater, 18 fms.

Holoporella brunnea. Reish, 1972.

Membranipora membranacea. Abbott, Soule, Oguri & Soule, 1973 (settling rack).

Membranipora perfragilis. Osburn, 1950.

Scruporcellaria varians. Osburn, 1950, off San Pedro breakwater, 126-138 fms.

Synnotum aegyptiacum. Robertson, 1905.

Thalamorporella californica. Robertson, 1905.

Penetrantia concharum. Osburn, 1953, intertidal.

Penetrantia densa. Osburn, 1953, San Pedro.

Suborder Ascophora

Athropoma cecili. Robertson, 1908.

Costazia costazi. Osburn, 1952, off San Pedro breakwater, down to 20 fms.

Cryptosula pallasiana. Osburn, 1952, along the shore in San Pedro.

Emballotheca latifrons. Osburn, 1952, off San Pedro.

Dakaria ordinata. Osburn, 1952, off San Pedro breakwater.

Hippodiplosia pertusa. Osburn, 1952.

Hippoporella gorgonensis. Osburn, 1952, off San Pedro breakwater.

Gemelliporella globulifera. Osburn, 1952, off San Pedro breakwater.

Microporella cribosa. Osburn, 1952, San Pedro Harbor.

Microporella setiformis. Osburn, 1952, off San Pedro.

Savignyella lafonti. Osburn, 1952.

Smittina landsborovi. Robertson, 1908.

Smittina maccullochae. Osburn, 1952, San Pedro Harbor.

Smittina cordata. Osburn, 1952, San Pedro breakwater.

Smittoidea prolifica. Osburn, 1952, off San Pedro breakwater.

Rhynchozoon grandicella. Osburn, 1952, off San Pedro breakwater.

ORDER CTENOSTOMATA

Bowerbankia gracilis. Osburn & Soule, 1953, Los Angeles Harbor.

Bowerbankia gracilis aggregata. Osburn & Soule, 1953, Los Angeles Harbor.

Immergentia californica. Osburn & Soule, 1953, San Pedro.

CLASS STENOLAEMATA

ORDER CYCLOSTOMATA

Tubulipora concinna. Osburn, 1953, off San Pedro.

Crisia occidentalis. Robertson, 1910.

Crisia maxima. Osburn, 1953, off San Pedro, 18 fms.

Crisulipora occidentalis. Robertson, 1910, off coast, 2-17 fms.

Lichenopora novaeselandiae. Osburn, 1953, near San Pedro.

PHYLUM ECHINODERMATA

CLASS ECHINOIDEA

Amphiodia urtica. Hartman, 1966.

Dendraster excentricus. Hartman, 1966.

Pentamera pseudopopulifera. Hartman, 1966.

CLASS OPHIUROIDEA

Amphiodia barbarae. MacGinitie & MacGinitie, 1968, buried 3-4 inches in littoral sand-mud flakes.

Amphiodia digitata. Hartman, 1966.

Amphiodia occidentalis. Hartman, 1966.

Amphiodia urtica. Hartman, 1966.

Ophioderma panamensis. MacGinitie & MacGinitie, 1968, under rocks at low tide.

Ophionereis annulata. MacGinitie & MacGinitie, 1968, in groups under rocks at San Pedro.

Pachythyone rubra. Hartman, 1966.

PHYLUM CHAETOGNATHA

Sagitta euneritica. Reish, 1972.

PHYLUM CHORDATA

SubPhylum Urochordata

Ascidia ceratodes. Fay & Johnson, 1971, Los Angeles Harbor breakwater.

Aplidium californicum. Fay & Johnson, 1971, Los Angeles Harbor breakwater.

Botrylloides sp. Fay & Johnson, 1971, Los Angeles Harbor breakwater.

Botryllus sp. Reish, 1972.

Ciona intestinalis. Barnard, 1958; Reish, 1961; Abbott, Soule, Oguri & Soule, 1973 (settling rack).

Cystodytes lobatus. Ray & Johnson, 1971, Los Angeles Harbor breakwater.

Diplosoma pizoni. Reish, 1972.

Pyura haustor. Fay & Johnson, 1971, Los Angeles Harbor breakwater.

Styela gibbsii. Fay & Johnson, 1971, Los Angeles Harbor breakwater.

Styela truncata. Fay & Johnson, 1971, Los Angeles Harbor breakwater.

SubPhylum Vertebrata

CLASS OSTEICHTHYS

Citharichthys stigmaeus. Chamberlain, 1973.

Citharichthys sordidus. Fitch & Levenberg, 1971; Young, 1964.

Clevelandia ios. Reish, 1959, 1972.

Cymatogaster aggregata. Chamberlain, 1973.

Cynoscion nobilis. Young, 1964.

Embiotoca jacksoni. Chamberlain, 1973.

Engraulis mordax. Chamberlain, 1973; Brewer, 1973.

Fundulus parvipinnis. Young, 1964.

Genyonemus lineatus. Chamberlain, 1973.

Hyperprosopon argenteum. Chamberlain, 1973.

Hypsopsetta guttulata. Chamberlain, 1973.

Lamna cornubica. Wilson, 1935, San Pedro.

Leptocottus armatus. Chamberlain, 1973.

Lepidogobius lepidus. Reish, 1959; Chamberlain, 1973.

Myliobatus californicus. Chamberlain, 1973.

Odontopyxis trispinosa. Chamberlain, 1973.

Otophidium scrippsi. Young, 1964.

Otophidium taylori. Chamberlain, 1973.

Paralichthys californicus. Young, 1964; Chamberlain, 1973.

Parophrys vetulus. Chamberlain, 1973.

Phanerodon furcatus. Chamberlain, 1973.

Pleuronichthys decurrens. Chamberlain, 1973.

Pleuronichthys ritteri. Young, 1964.

Pleuronichthys verticalis. Chamberlain, 1973.

Porichthys myriaster. Chamberlain, 1973.

Rhacochilus toxotes. Chamberlain, 1973.

Roncador stearnsii. Young, 1964.

Sebastes goodei. Chamberlain, 1973.

Sebastes paucispinis. Chamberlain, 1973.

Sebastes rubrivinctus. Chamberlain, 1973.

Sebastes saxicola. Chamberlain, 1973.

Sebastes sp. Chamberlain, 1973.

Seriphus politus. Chamberlain, 1973.

Squalus acanthias. Chamberlain, 1973.

Stereolepis gigas. Fitch, 1963.

Symphurus atricauda. Young, 1964; Chamberlain, 1973.

Syngnathus arctus. Herald, 1949.

Syngnathus californiensis. Chamberlain, 1973.

Trichiurus nitens. Fitch & Lavenburg, 1971, abundant in Los Angeles Harbor in the 1930's.

*U.S. GOVERNMENT PRINTING OFFICE: 1976 - 784-140/20 Region No. 9-1

EN

FILME

2 -84

DTIC